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APPLIED SURGICAL ANATOMY

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FOR THE USE OF STUDENTS AND PRACTITIONERS OF MEDICINE

BY

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PREFACE TO THE SECOND EDITION.

In the Preface to the original issue of this work it was pointed out that the study of Anatomy is relieved of much of its difficulty when it is approached on the practical side. Isolated details do not appeal to the faculty of interest, but when they are set forth in their natural relationship, and their practical application is shown, the mind grasps and recollects them with facility. As Anatomy is the most basic of all the medical sciences, a working knowledge of its data is indispensable for the study and practice of scientific medicine and surgery. The author has endeavored to embody these principles in this work, and to do it in such a manner as to answer the needs of both students and practitioners.

The plan of this volume has been developed from eighteen years' experience in teaching Anatomy. The author believes the form of presentation he has followed to be the best for didactic lectures, and furthermore that Descriptive Anatomy is most advantageously learned from text-books and in the dissecting room. The regional and topographical method of treating Applied Anatomy is likewise the most convenient for clinical purposes.

It is scarcely necessary to state that in order not to exceed the proper limits of a book designed for clinical and didactic use a most careful selection had to be made from the vast aggregate of knowledge constituting the modern science of Anatomy. If in parts the text may appear quite as much like an anatomical surgery as a surgical anatomy, it is because of the author's belief that this is the best way to complete the study of anatomy and to begin the study of surgery.

The author desires to acknowledge his indebtedness to the excellent words of Joessel, Tillaux, Merkel, and others, both for anatomical facts, the methods of their presentation, and for numerous illustrations. An original work on such a subject can no longer be written, nor could it have as much value as a volume duly recognizing the vast fund of information accumulated by tireless investigators. A single author can only hope to contribute a fair proportion of original knowl-

edge and to present a chosen aspect of the science in a clear and practical manner.

The number of excellent works on Applied Anatomy is large enough to render the exhaustion of an edition of anyone a fair presumption of its fitness to survive. An author can respond only in one way, namely, by striving to improve his work in revising it. This effort has been faithfully made in the new edition, and it may impartially be said to excel its predecessor in many particulars. The Sections on Cerebral Localization, Craniocerebral Topography, the Abdominal Viscera, or some of the Pelvic Viscera, and on the Spinal Cord have been re-written or largely amplified. Every page has been carefully revised, and its subject-matter elaborated wherever it seemed desirable. The volume has thus been enlarged by about eighty pages, and its illustrations increased by seventy-five engravings.

G. W.

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APPLIED SURGICAL ANATOMY.

CHAPTER I.

THE HEAD AND NECK.

THE HEAD.

General Considerations.—The head is anatomically the most essential and most complex part of the body. It is of great practical interest, for even its smaller parts are of importance to the life and well-being of man. In individuals of medium height and weight the head *measures* $\frac{1}{8}$ of the body height in men and $\frac{10}{75}$ in women, and *weighs* $\frac{1}{17}$ of the body weight in men (4 kg.) and $\frac{1}{16}$ in women (3.6 kg.). The larger the individual so much smaller is the head as compared with the total height and weight.

When the face looks directly forward the external auditory meatus and infra-orbital margin are in a horizontal plane. Such a position, the one most naturally assumed, is maintained by the posterior neck muscles and not by gravity, for the line of the latter lies in front of the transverse occipito-atlantoid axis of motion.

As compared with the human skull, that of the *higher apes* (chimpanzee, orang, etc.) shows marked differences, *i. e.*, the projection of the muzzle, the greater size and forward position of the face, the greater size of the intermaxillary bones, the posterior and oblique position of the foramen magnum, etc. *Idiots' skulls* approximate those of the lower animals in many respects, *i. e.*, large face, small cranium, etc.

The head shows a tendency to *asymmetry*. One error often compensates for another, and one is often astonished in the examination of the separate parts to find considerable deformity whose existence escapes a general observation. Individual differences in the head are marked, as they are elsewhere in the body, but we are accustomed to observe them more closely as they are the essential marks of individuality.

But besides the individual differences there are those of sex, age and race. Thus, the **female skull** looks immature, resembling that of a child, and is smaller, lighter, broader, and less high, the face and lower jaw are smaller, and the vertex is flattened. The circumference of the **skull at birth** is greater than that of any other part of the body. The skull at birth is characterized by the large size of the cranium and the small size of the face and the base; the absence of the mastoid process, the diploë, and all ridges; the presence of the anterior fontanelle and the prominence

of the frontal and parietal eminences.. It resembles more closely the skull of the lower animals than does the adult skull.

During the *first seven years* the skull grows very rapidly, at first more or less equally. During the first dentition the fontanelles close, the face broadens and enlarges, the jaws lengthen, and the zygomatic arches project. Later, the base of the skull lengthens and the face becomes deeper and somewhat longer. By the seventh year some parts have attained their growth, *i. e.*, the foramen magnum, the petrous portion of the temporal bone, the width of the body of the sphenoid and of the cribriform plate. Near the approach of *puberty* a second period of active growth begins, the face is elongated from the increased height of the nasal fossæ, alveolar arches and second teeth, and the expansion of the air sinuses. In *later years* the latter continue to expand, even up to old age, the crests and ridges develop and the frontal region elongates. In *old age* the skull atrophies, becoming thinner, lighter, and perhaps smaller by absorption on the surface and redeposit on the interior. The face becomes smaller by the loss of the teeth and the absorption of the alveolar processes.

The racial differences, although marked in typical examples, shade into each other. According to one classification we may distinguish: (1) the *prognathous*, or long-headed type, with projecting jaws and teeth, as in the negro; (2) the *pyramidal*, or broad, flat-faced type, with narrow forehead, as in the Mongolian or Esquimaux; and (3) the *oval* type of the European, with the length of (1), or even more, and the breadth of (2), but the teeth do not project, as in (1), nor the zygomatic arches, as in (2), and the forehead is full, laterally, and high. Again, skulls are classified as I. *Dolicocephalic*, or "long-headed," in which the occipital lobes overlap the cerebellum, and II. *Brachycephalic*, or "short-headed," in which the occipital lobes do not extend so far backward. Each division is subdivided into *orthognathous*, in which the jaws and teeth do not project, and *prognathous*, in which they do.

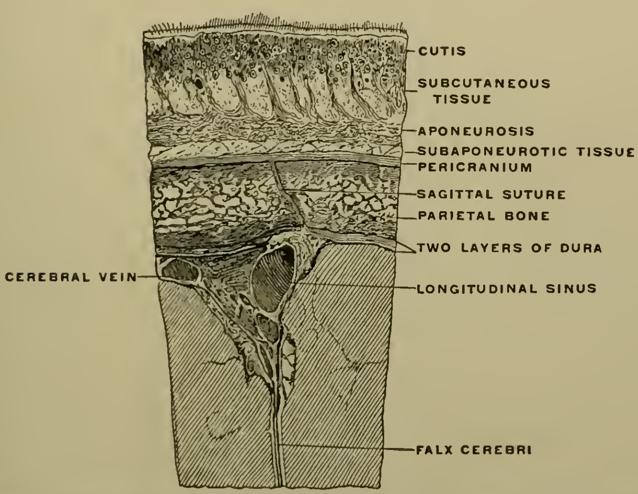
Other peculiar forms of skull are on the border line of pathological deformities, depending upon the premature closure of a certain suture which prevents the growth of the skull at right angles to that suture and forces it to grow in other directions, if at all. By the same process, extended to several sutures, microcephalus may result. The latter may be the result or cause of idiocy, in the latter case justifying operation (craniectomy).

The Scalp.

The soft parts covering the vault of the skull are arranged as in no other part of the body. There are five layers: (1) the skin; (2) the subcutaneous fatty tissue; (3) the occipitofrontalis muscles and aponeurosis; (4) the subaponeurotic areolar tissue; and (5) the pericranium. The *first three layers* are so intimately blended with one another, especially over the aponeurotic portion of the occipitofrontalis, that they form virtually a single layer, **the scalp** (Fig. 1).

1. **The Skin.**—The skin of the scalp is thicker than that in most regions of the body, and is thicker behind than in front. The *hair* is so strongly attached to the scalp that it has supported the weight of the body in many instances since the days of Absalom, as, for example, where it is caught in revolving machinery belts and the body is drawn after it. The entire scalp has also been torn off in such accidents. The hair should always be shaved around scalp wounds, otherwise it is impossible to make and keep them clean. Although the roots of the hairs may extend deeply into the subcutaneous fatty tissue, the numerous *sebaceous glands* associated with them are mostly superficial in the skin. These may develop into **sebaceous tumors** or wens, which are more common here than in any other part of the body. Owing to their superficial position, external to the aponeurosis, they are easily and safely removed.

FIG. 1



Frontal section of scalp and skull through the sagittal suture and the superior longitudinal sinus.

Care must be taken, however, in removing suppurating sebaceous cysts not to divide the aponeurotic layer, on account of the danger of infection of the loose tissue beneath.

2. **The Subcutaneous Tissue.**—The subcutaneous tissue, 5 to 6 mm. (¼ in.) in thickness, is composed of a great number of strong fibrous bands closely binding together the skin and aponeurosis and forming a multitude of small compartments enclosing lobules of fat. On account of this disposition of the fat it follows that fatty tumors are rare and that there is but little increase of it in obesity, though a perceptible decrease exists after long sickness. The falling out of the hair in such cases may be partly due to this fact.

The arrangement of this subcutaneous tissue, like that in the palm, admirably adapts it to resist pressure. It makes the density of the scalp such that in surface inflammations, as in erysipelas, the hairy scalp

is but little reddened, swells but slightly, and is extremely painful. Erysipelas of the hairy scalp may, therefore, be difficult to recognize. This layer attaches the skin so closely to the aponeurosis and muscle that the former moves with all the movements of the latter. Furthermore, this layer contains the **vessels** which supply the three layers of the scalp. These vessels are closely connected with the fibrous partitions of this layer, so that in wounds of the scalp the vessels which are divided are unable to retract or contract, hence hemorrhage is free and is not spontaneously arrested.

3. **The Aponeurosis.**—The aponeurosis occupies the space between the two muscular portions of the occipitofrontalis, in front and behind. Laterally it extends down over the temporal fascia, and becomes connected with it and, hence, with the zygomatic arch.

4. **The Subaponeurotic Areolar Layer.**—The subaponeurotic areolar layer is a layer of loose connective tissue whose looseness serves, like a serous membrane, to facilitate the movement of the scalp upon the pericranium, a condition which is more marked in the young than in the old. This looseness of attachment allows the gaping of scalp wounds and the ready separation of large flaps of scalp by injuries, operations, scalping by Indians, or in autopsies. It is known as the **dangerous area** of the scalp, for its loose structure allows the wide and rapid spread of inflammation and pus, posteriorly as far as the superior curved line, anteriorly to the superciliary ridges, and laterally to the level of the zygoma. Wounds or incisions which extend through the entire scalp and open into this layer are much more serious than more superficial ones on account of the more serious consequences of infection. This layer contains but few bloodvessels which cross it to enter the pericranium, otherwise large effusions of blood would be far more common here than they are. *Tumors* situated external to the aponeurosis move with the scalp; immovable growths are probably beneath the aponeurosis.

5. **The Pericranium.**—The pericranium is remarkable for its slight adherence to the bone except along the sutures, where it is attached to the suture membrane and is thus continuous with the dura, as it is also at the foramina. Hence inflammation may extend by continuity from the pericranium to the dura at the foramina and sutures where the two become continuous. In the adult it is more adherent to the bone than in children. It follows also that the pericranium may be widely stripped up from the underlying bone in extensive scalp wounds. Such an injury is of less importance than we would expect from analogy with similar injuries of the periosteum elsewhere. The skull bones seldom necrose under such circumstances, for they derive their main blood supply from the vessels of the diploë and dura. For a similar reason loss of bone in the vault of the adult skull due to injury, necrosis, or operation is, as a rule, not repaired, for neither the pericranium nor the dura reproduce bone as does the periosteum.

Vessels of the Scalp.—The vascularity of the scalp is greater than that of any other part of the surface. Flaps of scalp, however large and extensively stripped up, almost always live, for the scalp carries

its own blood supply, which enters at the pedicle of the flap. Sloughing and gangrene from pressure are rare, owing to the density of the scalp tissue in which the vessels run. Unlike other regions of the body, where vessels of any size are subfacial, the vessels of the scalp lie in the subcutaneous tissue alone.

The Arteries.—The arteries come from the occipital, posterior auricular, and superficial temporal branches of the external carotid and from the supra-orbital and frontal branches of the ophthalmic. Each vessel converges upward toward the vertex of the skull and anastomoses freely with the adjoining ones and with its fellow of the opposite side. It follows that *incisions* should be planned as far as possible to radiate from the vertex, or, if horseshoe-shaped, to have the base below. To *prevent hemorrhage* during an operation, rubber tubing may be tightly drawn around the base of the scalp, or, to diminish it, overlapping, interrupted, temporary sutures may be applied between the incision or flap and the base of the scalp, from whence the arteries pass upward. The *frontal artery,* emerging at the inner angle of the orbit on each side, enters at the base of and nourishes a frontal rhinoplastic flap. The *temporal artery,* with its vein and the auriculotemporal nerve behind it, ascends between the condyle of the jaw and the external auditory meatus over the posterior root of the zygoma and divides into its anterior and posterior branches 3.7 to 5 cm. ($1\frac{1}{2}$ to 2 in.) above the latter. Its pulsation is a convenient guide to the anesthetist. It presents in a high degree the tortuosities of the arteries of the head, especially its anterior branch, and in the aged it affords early evidence of arterial sclerosis. It is the most frequent situation for cirsoid aneurysm, and is more frequently wounded than almost any other artery of the body. The *posterior auricular artery* and nerve run in the angle between the ear and the mastoid process. The *occipital artery* ascends a finger's breadth behind the mastoid process and reaches the scalp, with the great occipital nerve, a little posterior to a point midway between the mastoid process and the occipital protuberance. These arteries all share the peculiarity of being subcutaneous instead of being subaponeurotic.

The Emissary Veins.—The emissary veins connect the dural sinuses, and indirectly the veins of the pia-arachnoid, with the superficial veins at certain points through apertures in the skull, and hence are of considerable practical importance. They afford a channel for the spread of inflammation from the surface, to the sinuses or meninges, thereby causing sinus thrombosis or meningitis, as in cases of erysipelas and suppuration of the scalp or necrosis of the cranial bones. Their presence adds greatly to the seriousness of injuries and diseases of the scalp. They also assist in equalizing the intracranial pressure, and for this purpose are most developed in early life, during the period of brain growth.

Besides very numerous small veins, the most constant and important of the larger emissary veins connecting with the veins of the scalp are: (1) the vein passing through the mastoid foramen which connects the lateral sinus with the occipital (or posterior auricular) vein; (2) the vein passing through the posterior condylar foramen which connects

the sigmoid sinus with the deep veins at the back of the neck; (3) the vein passing through the parietal foramen which connects the superior longitudinal sinus with the veins of the scalp. The *mastoid emissary vein* accounts for the practice of bloodletting or blistering behind the ear in some cerebral affections and for the edema behind the mastoid process in lateral sinus thrombosis. For the other emissary veins see any descriptive anatomy.

The veins of the scalp are also connected by many minute veins with the **veins of the diploë**. The latter are not well developed until after the tenth year, when the diploë develops and they are separate for each bone until the ossification of the sutures (Testut). The veins of the diploë communicate, the anterior two (frontal and anterior temporal) with the surface veins (supra-orbital and deep temporal), the posterior two (posterior temporal and occipital) with the lateral sinus. The anastomosis between the supra-orbital and other facial tributaries at the inner angle of the orbit with the ophthalmic vein affords a free communication between the extra- and intracranial circulation, as the ophthalmic is a tributary of the cavernous sinus. Thus, we see the number of channels, and there are other less conspicuous ones, through which inflammation can spread from the surface to the interior of the skull.

The Lymphatics.—The lymphatics of the scalp may be divided into three groups: (1) the occipital emptying into the suboccipital nodes; (2) the posterior parietal emptying into the mastoid nodes; and (3) the anterior parietal and frontal which empty into the parotid nodes. Some vessels from the frontal region end in the submaxillary nodes. A knowledge of these regions and their nodes is of service in the diagnosis of scalp troubles in which they are affected.

With regard to the **nerves** which supply the scalp it is only necessary to say that those which are branches of the fifth nerve are not infrequently the seat of neuralgia, especially the *supra-orbital nerve,* less often the auriculotemporal. The former emerges from the orbit at the supra-orbital foramen or notch, at the junction of the inner and middle thirds of the supra-orbital margin. Here it may be readily found and divided or resected in some forms of obstinate frontal headache due to neuralgia of this nerve. The inner branch reaches back to the middle of the parietal bone, the outer branch as far as the lambdoid suture. As the fifth nerve supplies the dura as well as the greater part of the scalp, pain due to a lesion of the former may be referred to a similar point of the latter so as to be of use in localization.

Wounds.—Wounds of the scalp do not gape unless the aponeurosis or muscle is divided. Those wounds gape most which are transverse to the muscle fibers, next those transverse to the aponeurotic fibers, and those gape least which are parallel with them, *i. e.,* anteroposterior. As the scalp is firmly stretched over the hard bone beneath, contused wounds often appear as cleanly cut as incised wounds. Wounds resembling incised wounds may also be produced from within by the sharp edge of the superciliary ridge when struck by a blunt object.

Bleeding.—Bleeding from scalp wounds is very free, and unless properly treated very prolonged. There is little or no tendency to the spontaneous arrest of hemorrhage, for the arteries, owing to their adhesion to the tissues of the scalp, are unable to retract or contract when divided, and it is by this process that bleeding is ordinarily spontaneously arrested. This adhesion of the vessels to the fibrous partitions and the density of the scalp account for the difficulty of tying a bleeding artery in the scalp, hence to arrest hemorrhage we often depend upon pressure, transfixion, or upon suturing the edges of the wound firmly together. Fortunately, as we have seen above, there is very little danger of sloughing on account of pressure. In addition to the arrest of bleeding, we have to think of the possibilities of inflammation in scalp wounds.

Inflammation or Abscess.—Inflammation or abscess in the scalp may occur in one of three situations: (1) in the subcutaneous tissue; (2) between the aponeurosis and the pericranium; and (3) beneath the pericranium. Abscesses of the first variety are small and spread only with the greatest difficulty in the dense tissue. In the second situation inflammation or abscess may be very serious on account of its easy spread in the loose tissue and the danger of the infection extending within the cranium. Inflammations of this kind may follow scalp wounds dividing the aponeurosis, and the chief danger of these wounds lies in such inflammations. The inflammation may undermine the entire scalp, and is limited only by the attachments of the aponeurosis as given above. Abscesses extending to the limits of this area should be opened and drained above the line of attachment of the aponeurosis. The scalp does not perish even in the most extensive cases, as it carries its own blood supply; but the wounds which lead to the abscess or are made to relieve it are often slow to heal, as the abscess walls fail to obtain perfect rest, owing to the movements of the occipitofrontalis muscle. Abscess beneath the pericranium is limited to the surface of one bone, as this membrane is adherent to the suture membrane. It is most often the result of necrosis of the cranial bones.

Hematomas.—Hemotomas of the scalp may be classified in the same manner as abscess. They occur most frequently outside of the aponeurosis in the subcutaneous tissue which contains the greater part of the blood-vessels. In this situation the extravasation of blood is usually small and sharply limited by the density of the tissues, and is confined to the area where the tissues are lacerated by the violence. Such extravasations of blood produce a tumor on the surface whose thin edges become hard from the coagulation of the thin layer of blood, while the thicker centre remains soft for a time. A firm, sharp margin often separates these two parts, which may lead to an error in diagnosis by mistaking it for the margin of a fracture of the skull and the soft centre for the depression of an area of the skull. This error may be avoided by observing the projection of the blood tumor on the surface and by moving the scalp back and forth, when the supposed depressed area moves with the scalp over the surface of the skull. Again, the sharp margin of the hematoma will pit on firm pressure, so that the bone is felt beneath. Owing to its

proverty in bloodvessels, the loose tissue beneath the aponeurosis is not often the seat of a hematoma except as the result of fracture of the skull, or when the aponeurosis is torn by the injury. When they occur here they may attain a large size and may similarly present hard edges and a soft centre, simulating depressed fracture, from which they cannot be so readily distinguished by moving the scalp.

Extravasations of blood beneath the pericranium are limited in area to one bone, and may be diagnosticated by this fact. They are commonly called *cephalhematomata,* are usually congenital in orgin, due to pressure on the head at birth, and hence are more frequent in males owing to the larger size of the head. They are most common over the parietal bone and on the right side, which is most exposed to pressure. Besides these blood tumors beneath the pericranium others occur rarely which have a different origin and are distinguished by disappearing on pressure, in whole or in part, or even in the upright posture. Such tumors according to their position are connected either with the veins of the diploë or the dural sinuses through an opening which may be the result of injury, disease, or congenital defect. When communicating with the superior longitudinal sinus they are median and receive a faint pulsation from the brain.

The Temporal Region.

The temporal region varies in some respects from the scalp proper as to the soft parts covering it. The limits of this region may be taken to be the upper border of the zygomatic arch, the external auditory meatus, and the base of the mastoid process below and the curved superior temporal ridge above. The latter ridge connects the base of the mastoid bone with the external angular process of the frontal bone and rises 7 to 8 cm. (about 3 in.) above the level of the zygomatic arch. This region corresponds to the temporal fossa, and its upper limits may be determined by making the temporal muscle to contract. The various layers of soft parts common to this region and the occipitofrontal are identical above, where they really form a part of the scalp, but change in character below. Thus the skin below is less dense, less thick, and less adherent to the subcutaneous tissue and is wanting in hair below and in front. The subcutaneous tissue below becomes loose and resembles that elsewhere in the body, and the arteries are no longer intimately adherent to its septa. The aponeurosis passes down over and becomes attached to and continuous with the temporal fascia.

The Temporal Fascia.—The temporal fascia, whose form represents exactly that of this region, is very dense and unyielding, so that in the case of an injury reported by Denonvilliers a lacerated wound of this fascia was at first mistaken for a fracture of the skull. In its lower fourth it is double, enclosing fat and the orbital branch of the temporal artery between its two layers, which are attached to the outer and inner aspects of the upper border of the zygomatic arch. Between it and the bone is an osseo-aponeurotic space which is deepest in front, 2.5 cm.

(1 in.), and narrows behind and above until we reach the attachment of the fascia to the bone. This space lodges the temporal muscle and deep temporal vessels and nerves. It is hermetically closed above by the attachment of the fascia to the temporal ridge, while below it is directly continuous with the zygomatic fossa, so that surgically the two fossæ form but a single region. Hence abscess, etc., in the temporal fossa is prevented by the firm fascia from opening above the zygoma and tends to extend downward into the zygomatic fossa and the neck. Owing to the density of the fascia, pathological collections beneath it do not show on the surface.

As in the scalp, inflammatory products or blood may collect in the subcutaneous or subaponeurotic layers, in which situations they may be wholly above the zygoma or sink in part below its level. Subcutaneous effusions lie external to the zygomatic arch, while those beneath the fascia are internal to the arch. In the temporal region the pericranium is much thinner and more adherent to the bone, while the dura is less so than it is above; hence subpericranial extravasations are rare, while epidural extravasations are more common than elsewhere.

As the muscle is separated from the fascia in the lower third of this region by a mass of fat, continuous with the abundant masses in the zygomatic fossa, we see that there are three distinct layers of fat between the surface and the muscle: (1) subcutaneous; (2) interfascial; and (3) subfascial. This fat diminishes in wasting diseases, giving a sunken appearance to the temporal region, and bringing the zygomatic arch and the malar bone, below and in front, into prominent relief.

The Bony Cranium.

Surface Landmarks.—Those that can be determined through the overlying scalp are of the most surgical importance in relation to craniocerebral topography. The **external occipital protuberance**, or **inion**, is readily felt in the median line. It is the thickest part of the vault, and corresponds about to the torcular Herophili on the inner surface. The **glabella**, the median smooth area between the superciliary ridges of the frontal bone, can be felt just above the notch (*nasion*) at the nasofrontal suture. The **external angular process** of the frontal bone at the outer end of the supra-orbital ridge is readily felt. Measurements are taken from its upper and outer part. It should not be confounded with a projection on the back of the frontal process of the malar bone below it. The *zygomatic arch*, the *external auditory meatus*, and the *mastoid process* can all be readily seen or felt. The upper branch of the posterior root of the zygoma (*supramastoid crest*) running into the posterior part of the temporal ridge can be felt above and behind the external auditory meatus. The *parietal eminence* is used as a landmark, but is not a well-marked one. To determine it the scalp should be shaved, and it can be more accurately determined when the skull is bared. It is more prominent in young skulls.

In addition to these palpable or visible landmarks and by means of them we can determine **the position of the sutures.** The **bregma,** the site of the anterior fontanelle where the sagittal and coronal sutures meet, lies at the intersection of the median line with a vertical line drawn from a point just in front of the external auditory meatus. The *coronal suture* lies in a line from the bregma to the middle of the zygomatic arch. The **pterion,** where the frontal, parietal, and great wing of the sphenoid meet, lies on this line 3 to 3.7 cm. ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.) behind the external angular process of the frontal and about the same distance above the zygoma. The *sagittal suture* is median and extends between the bregma and the **lambda.** The latter corresponds to the posterior fontanelle and is about midway between the bregma and inion (external occipital protuberance), or 7 cm. ($2\frac{3}{4}$ in.) above the latter. The *parietal foramen* is about 4 cm. ($1\frac{3}{5}$ in.) above the lambda. The *lambdoid suture* joins the sagittal at the lambda and extends thence along a line drawn to the posterior end of the base of the mastoid process, or it may be represented by the posterior two-thirds of a line from the lambda to the apex of the mastoid. The *asterion,* at the postero-inferior angle of the parietal bone where the lambdoid and parietomastoid sutures meet, lies on the last-mentioned line 4.5 cm. ($1\frac{3}{4}$ in.) behind the meatus and on a level with the zygoma. The summit of the *squamous suture* is about 5 cm. (2 in.) above the zygomatic arch. It should be remembered that the frontal suture, between the two halves of the frontal bone, sometimes persists, and should not be mistaken for a fracture.

The sutures, besides interlocking in a serrated or dentated manner, *are bevelled* alternately at the expense of the outer and inner aspect. Thus, in the coronal suture the frontal overlaps the parietal above and is overlapped by it below. In injuries to the skull *diastasis* or separation of the bones at the sutures occurs in but a very small percentage of cases, and then usually in connection with an extensive fracture. It is naturally more common in young than in adult skulls. The squamous suture is the one where diastasis is most common, or when associated with fracture, the sagittal and coronal sutures. The *suture membranes* in young skulls are thick and vascular, so that a surface inflammation may travel through them to the internal surface of the cranium, and vice versa. In infants at birth they are so broad as to allow the bones to slide upon one another and thus provide for the moulding of the head in its passage through the pelvis. In *hydrocephalus* the sutures, especially those around the parietal bone, become widely separated and the fontanelles form large openings whose closure is much delayed. The *posterior fontanelle* is normally closed at birth, or a month or two later, the *anterior* during the second year, up to which time it acts as a safety valve for the rapidly varying intracranial pressure. It may persist much longer, even to adult life. The fontanelles aid in determining the position of the infant's head during parturition.

As the sutures with their membranes allow the rapid growth of the skull, their premature closure prevents the growth of bone in a line at right angles to them. This causes a deformity in shape of the skull or,

if more general, a small size (*microcephalus*) of the skull, which may be the cause or, more often, the result of arrested brain development or idiocy. If it be the cause of idiocy, microcephalus calls for *craniectomy* to allow for the growth of the brain. Such premature ossification may be due to rickets.

The sutures assist slightly to break the force of shocks and diminish the liability of fracture, hence the latter would seem more likely to follow a slight injury after the closure of the sutures, which occurs at varying periods after middle life. This closure begins, as in the long bones, at the end of the suture last ossified, *i. e.*, near the fontanelles, and occurs first in the sagittal, last in the squamous suture. It is said to begin when the weight of the brain ceases to increase, and may be complete by the age of eighty (Tillaux).

The *Wormian bones* occur in varying numbers and sizes along the sutures, most often in the lambdoid suture, and may be mistaken for fragments due to fracture. One of these bones, the *epipteric bone*, is found at the pterion and usually joins the great wing of the sphenoid, of which it may be thought to be a broken fragment. It may be met with in trephining for the middle meningeal artery.

In *craniotabes* ascribed to rickets or inherited syphilis, the softened skull is deformed and flattened in the occipital and posterior parietal regions by the pressure of the head resting largely on this part. In these same areas the bone may become very much thinned or even wanting by the combined pressure from within and without.

Conditions Depending upon Errors of Development.—The frontal, parietal, and squamous portion of the temporal and the part of the occipital above its highest curved line are formed in membrane, the base of the skull in cartilage. The entire absence of that part formed in membrane is occasionally found as an anomaly. The squamous portion of the occipital bone is ossified from four centres, a pair above the highest curved line and a pair below. The upper pair may form a separate bone, the *interparietal bone* of the lower vertebrates, and the suture between this and the part below should not be mistaken for a fracture. More commonly there persist two lateral fissures, as at birth, or median fissures between the lateral centres, and these fissures also should not be mistaken for fractures.

Certain tumors of congenital origin, containing cerebral contents and called **cephaloceles** or "cerebral herniæ," occur as the result of such defective development. They are usually situated in the median line and most often in the occipital, next in frequency in the nasofrontal region. *Occipital cephaloceles* generally occur through a median fissure in the occipital bone, either above or below the external occipital protuberance; anterior or *sincipital cephaloceles* through the nasofrontal suture. More rarely such tumors occur through other abnormal apertures, especially at the base of the skull. When the sac of a cephalocele, which is formed by the outer cranial membranes, contains cerebrospinal fluid alone the tumor is called a **meningocele**; when it contains brain substance, an **encephalocele**. A **hydrencephalocele** is an encephalo-

cele containing a cavity filled with fluid which is often connected with the cerebral ventricles.

The *parietal fissure* is a narrow gap extending from the parietal eminence to the sagittal suture about 2.5 cm. (1 in.) in front of the lambda. It is often seen about the fifth month of fetal life as a cleft between the radiating ossific spicules, but it usually closes. When present on both sides the lozenge-shaped gap is known as the *sagittal fontanelle.* The fissure should not be mistaken for a fracture.

Construction and Lesions of the Bones of the Cranial Vault.—In the adult these bones are composed of compact *outer and inner tables* and an intervening cancellous-like layer, the **diploë**. This is not present in the thinnest part of the skull or in children's skulls, and does not form until about the tenth year. The *blood supply* of these bones is contained largely in the diploë, which receives but little blood from the vessels of the pericranium, more from those of the dura. Some of the consequences of this we have already seen (pp. 20, 22). The veins of the diploë empty into both the dural sinuses and the surface veins. As the vessels of the diploë communicate with those of the dura and the dural sinuses, inflammatory lesions of the bone may extend to the sinuses and lead to sinus thrombosis, with the danger of pyemia, or to the dura and cause pachymeningitis.

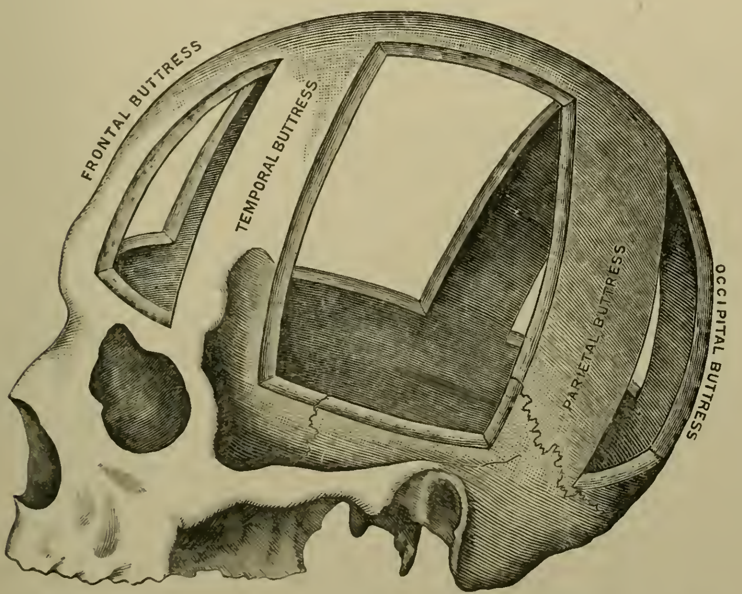
Inflammatory Lesions.—Inflammatory lesions of the bones commonly lead to **caries or necrosis**, which is not uncommon on the vault of the skull, and most often involves the frontal and parietal bones. Owing to its poorer blood supply and its exposure to injuries the external table is more often involved alone than the internal table. *Syphilis* and *tuberculosis* are the most common causes of caries or necrosis of these bones. Many cases result from injury, especially when the wound is infected, and but few cases are spontaneous or idiopathic. Besides the special dangers, mentioned above, of sinus thrombosis and meningitis, pus and granulation tissue may collect between the bone and dura and cause pressure on the brain and cranial nerves, but fortunately such a collection of pus here is not common. When the disease of bone involves the whole thickness of the skull the pulsations of the brain may be seen or felt in the gap produced. Necrosis with separation of extensive areas, even of the entire vault, has been reported (Saviard). A peculiarity of necrosis of the cranial vault is that no involucrum is formed and the bone is not reproduced. As a rule, stripping up of the dura is not followed by necrosis.

The average **thickness** of the bones of the cranial vault is 5 mm. ($\frac{1}{5}$ in.), but this is liable to wide variation in different parts of the same skull and in different skulls. Thus it is very thin and translucent in the squamous portion of the temporal, the anterior inferior angle of the parietal, and in the inferior or cerebellar fossæ of the occipital squamosal; while it is very thick at the occipital protuberance, the mastoid process, the lower part of the frontal bone, and along the ridges that bound the grooves for the superior longitudinal, the lateral and occipital sinuses. It is alternately thick and thin at the base. Again, the inner surface of the cranium is marked by *depressions or grooves:* (1) for the cerebral convolutions;

(2) for the dural sinuses; (3) for the meningeal arteries (especially the middle meningeal); and (4) for the Pacchionian bodies. Hence the inner and outer tables of the skull are not parallel with one another.

These facts should be borne in mind in **trephining**. The pin of the trephine should not be made to penetrate over 3 mm. ($\frac{1}{8}$ in.), and in many regions 1.5 mm. ($\frac{1}{16}$ in). The trephine, burr, or drill should not be applied over the course of the sinuses, over the position of the frontal sinuses (often of large size in the aged), nor over the position of the middle meningeal artery, unless it is desired to expose these parts. As the suture membrane blends with the dura, these instruments should not be applied over the sutures for fear of wounding the dura. From time to time

Fig. 2



Preparation of skull, showing the principal arches of strength or buttresses of resistance. (Thompson, *l. c.*, after Dolbeau and Félizet.)

the groove made by the trephine should be tested in its entire circumference by a probe to see if it is through where the bone is thinnest. The bleeding in a trephine wound comes almost exclusively from the diploë.

The skull presents certain stronger **ridges** or **buttresses** where the bones are thicker or stronger and between which they are thinner and more readily fractured. These buttresses pass from the vault to the base at the foramen magnum and serve to unite the two parts into one solid framework. Thus one buttress is represented by the median part of the frontal, the ethmoid, the body of the sphenoid, and the basilar portion of the occipital. This *anterior buttress* is continuous along the middle line of the vertex with the *posterior buttress*, which passes through

the occipital protuberance and crest to the foramen magnum. Two *lateral buttresses* exist: the anterior, represented by a ridge of bone from the vertex to the exterior angular process of the frontal and thence through the great wing to the body of the sphenoid, and the posterior, running through the parietal eminence, mastoid process, posterior part of the petrous bone, and the jugular process to the occipital condyle.[1]

The bones of the skull and the skull as a whole are elastic. This **elasticity** is greater in the infant than in the aged, but even the adult skull is less brittle than commonly supposed. The yielding character of the *infant's skull* is shown in the artificial deformity of the flat-headed Indian, produced by pressure, and it has been asserted (Guéniot) that in infants considerable deformity may be produced by the weight of the brain, by allowing them to lie always upon one side. In addition in the infant there is much cartilage and membrane between the bones. Hence the skull of an infant is not easily fractured. The probable effect of a blow is to indent the skull. During delivery the infant's skull, most often the parietal bone (right parietal in L. O. A. presentations), may be flattened by pressure against the sacral promontory or by the use of the forceps. Though a hemorrhage (*cephalhematoma*) often occurs beneath the indented area, between the bone and pericranium, real fracture is rare.

Fractures of the Skull.—That the liability of the skull to fracture is not much greater is due to the following anatomical conditions: its elasticity, its rounded form favoring glancing blows, the density and mobility of the scalp, the make-up of the skull by a number of bones, composed of two plates or tables with intervening spongy bone, separated by sutures and suture membranes, which act to a slight extent as buffers, and the mobility of the head on the spine.

Fractures of the skull vary from a mere crack or fissure to an extensive crushing in, with depression. They may be simple or compound. Although, as a rule, the entire thickness of the bone is involved in fractures of the skull, yet the *external table alone* may be broken or even depressed into the diploë or into the frontal sinuses. More rarely the *internal table* may be fractured without injury of the outer table. This injury can be explained and illustrated as follows: An injury causing fracture tends to flatten out the skull over the area where the violence is applied, and is like bending a barrel hoop so as to straighten it. Like the barrel hoop, it gives way first on the inner or concave surface, and if the force is not continued this surface alone may be broken. For the same reason, in complete fractures the inner table is fractured first. In addition this *inner table* is *most extensively fractured* in most cases, for (1) it is thinner and more brittle (hence called the "vitreous table"); (2) the force as it travels from the outer table through the diploë to the inner table passes in a radiating manner so as to reach the inner plate in a more diffused form; (3) the inner table is a part of a smaller circle; and (4) as the force tends to flatten out the arch, the bony particles of the outer table

[1] Dupluy and Reclus, vol iii, p 461.

are compressed together and those of the inner table are forced asunder, as in straightening a barrel hoop over the knee. Owing to its elasticity, the outer table recoils after the injury, diminishing its depression, while the inner table remains more depressed on account of its inelasticity.

In general, **fracture of the vault** occurs from a given violence when the limit of its elasticity is exceeded, as illustrated in the straightening of a barrel hoop. Fractures of the vault are due to *direct violence*, and usually occur at the point where the force is applied. When a considerable force is applied over a limited area, this area of the skull is usually depressed. When it is applied over a large surface (as in falls from a height), the entire globe of the skull is compressed or flattened in the direction in which the force acts, and lengthened or pulled apart in a direction at right angles to this. Two forms of fracture may result: (1) a "**compression fracture**" at the point where the skull is pressed together by the direct violence; and (2) a "**bursting fracture**," where the skull has been lengthened and forced asunder. The latter form is due to indirect violence, and occurs more often at the base than on the vault of the skull.

Symptoms.—The symptoms and danger of fractures of the vault depend very largely on the concomitant brain lesions: (1) concussion; (2) contusion of the brain; and (3) intracranial hemorrhage. Fractures of the *temporal region* are in general more serious than similar fractures of the rest of the vault, for the *middle meningeal artery* is often injured, and the resulting hemorrhage causes compression of the brain. The escape of *cerebrospinal fluid* from a fracture of the vault is not common, though it has been observed in compound fractures and in simple fractures in children (resulting in a fluctuating tumor beneath the scalp). It indicates injury of the dura.

It is interesting to note how the construction of the skull resists the fracturing force in many ways. A blow on the vertex in the parietal region tends to drive the upper borders of the parietal bones inward and the lower borders outward. The latter tendency is resisted by the overlapping great wing of the sphenoid and the squamous bone. The latter is buttressed by the zygomatic arch and this in turn by the malar and the bones of the face, hence the pain in the face said to be felt in falls or blows on the top of the head. When the frontal suture exists, a tendency of the lower part of the frontal bone to be forced outward in blows on the median parts of the frontal is similarly resisted by the overlapping anterior inferior part of the parietal and the great wing of the sphenoid. A blow on the upper part of the frontal bone is transmitted to the parietal, on which this part of the frontal bone rests, owing to the bevelling of the upper part of the coronary suture. Blows on the occiput are less safeguarded by anatomical arrangements, except by its articulation with the elastic vertebral column. *Gaseous tumors* beneath the scalp have been described as a sequel to fractures of the skull in which one of the cavities containing air has been involved in the fracture, *i. e.*, the various sinuses, mastoid cells, etc.

Fractures of the Base.—Fractures of the base may be due to (1) direct violence, (2) indirect violence, and (3) extension of a fracture of the

vault. Fractures of the base by *direct violence* occur in cases where a foreign body is forced through the orbital, nasal, or pharyngeal roof, or through the nape of the neck in the posterior fossa. They are not common. One form of fracture of the base by *indirect violence* is illustrated by the fracture of the cribriform plate of the ethmoid or the orbital plate of the frontal by a blow on the root of the nose or the lower part of the frontal bone; and by the fracture of the glenoid fossa by the condyle of the jaw driven violently upward, as in falls or blows on the chin. In this manner the condyle has been actually thrust into the cranial cavity (Chassaignac). Again, in falls upon the buttocks, less often upon the feet or knees, the force has been transmitted along the vertebral column, especially when it is kept rigid by muscular action, and has resulted in the fracture of the base in the occipital region, often in a "ring fracture" around the foramen magnum. A similar fracture may possibly result from a blow on the head just as the handle of a hammer may be driven in either by a blow on the end of the handle or by one on the head of the hammer.

Mechanism.—The mechanism of the majority of fractures of the base has been much discussed. The former theory that many were the result of *contrecoup,* or a focussing of the force at the opposite pole to that struck, has been abandoned. Possibly a very few cases may be so explained, though perhaps better as "bursting" fractures. Aran and others showed that many fractures of the base were fractures by *irradiation, i. e.,* the result of fractures of the vault spreading to the base by the shortest route irrespective of the sutures; hence fractures of the frontal region spread to the anterior fossa, those of the parietal region to the middle fossa, and those of the occipital region to the posterior fossa. This was especially the case in linear fissures, the result of diffused violence, as in falls upon the head. In general, when the violence is not excessive, Felicet found that these fractures seem to run in the weaker areas between the ridges or buttresses (see p. 29). These explanations do not fit all cases, or even the majority, as well as does that of "*bursting*" *fractures* (see p. 31). As seen above, the latter are indirect fractures and probably comprise most of the fractures of the cranial base. Fractures due to bursting (*i. e.,* most fractures of the base) run parallel to the axis of pressure, those due to compression run at right angles to this axis. As fractures of the base run in the direction of the violence that inflicts the injury, or parallel to it, we can fairly well predict the course of a fracture of the base if we know the direction of the force and the point struck. Bursting fractures are most likely to occur where the skull is weakest, which is at the base, owing to the numerous foramina, etc. (see Figs. 3 and 4). The thin orbital plate and occipital bone and the thicker petrous bone, weakened by its foramina and canals, are the parts most often fractured.

In fractures of the base there is usually an escape of *blood* and often of *cerebrospinal fluid* externally. As the weakest part of the petrous bone is generally involved, which lies in the plane passing through the middle ear, the internal ear, and the internal auditory meatus, the tympanic membrane is commonly ruptured, and this allows of the escape of blood

PLATE I

FIG. 3

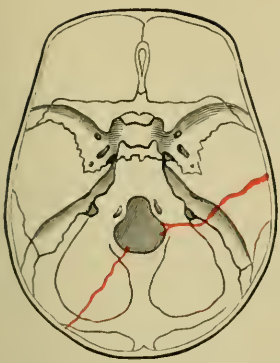
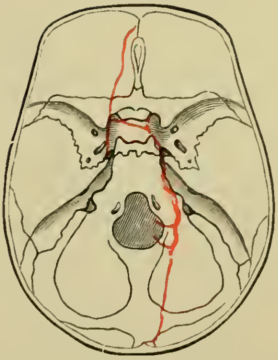
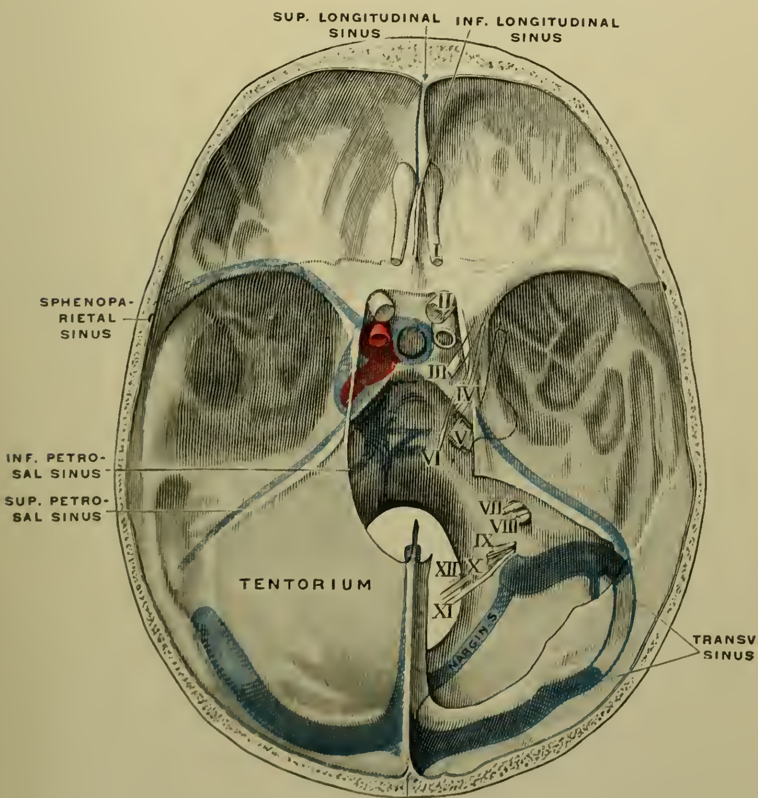


FIG. 4



Illustrating Lines of Bursting Force in Basal Fractures. (Wahl.)

FIG. 5



Interior of the Base of the Skull Covered by Dura, showing the sinuses, nerve exits, and tentorium. Cranial nerves are numbered in Roman figures. (Merkel.)

from the ear, a symptom so common in fractures of this region of the base. This blood may be derived from the vessels of the tympanum and its membrane or from an intracranial source, sometimes from the rupture of one of the sinuses about the petrous bone. Hence the escape of blood does not prove the existence of a fracture. If the membrane is not ruptured the blood may pass through the Eustachian tube and escape at the nose or mouth. In addition to bleeding from the ear the flow of cerebrospinal fluid is sometimes observed. This occurs when the dura and arachnoid, or their tubular prolongation in the internal auditory meatus, are torn by the fracture, which connects the subarachnoid space with the tympanum, whose membrane is lacerated. In fractures of the base of the skull one of the cranial nerves may be injured and paralyzed. The facial is the nerve most often involved alone or together with the auditory.

In fractures of the *anterior fossa* the blood escapes into the nose, mouth, or orbit. In the latter case it produces a subconjunctival ecchymosis, rarely an exophthalmos. Bleeding into the nose may run back into the mouth, and in bleeding either into the mouth or nose the blood may be swallowed and subsequently vomited. When bleeding from the nose or mouth occurs as the result of a basal fracture, the latter involves the cribriform plate or the body of the sphenoid. In bleeding from the nose the greater part of the blood probably comes from the torn mucosa of the nasal roof. If there is a discharge of cerebrospinal fluid from the nose there must be a laceration of the nasal mucosa and of the dura and arachnoid. In fracture of the base in the *posterior fossa* of the skull the blood may appear as an extravasation about the mastoid process or the nape of the neck.

Symptoms.—The symptoms and serious nature of basal fractures depend upon the concomitant *intracranial lesions*. *Meningitis*, due to infection of a fracture of the base which opens into a cavity connected with the air, is rare as a cause of death as compared with the intracranial lesions due to the injury. The base of the skull is rather *inaccessible to operations* on account of its location.

Owing to a lack of reparative vitality, repair after fractures of the skull is very slow and bony union occurs only when the fragments are separated by a very small interval. The new bone is produced mostly by the diploë and more by the dura than by the pericranium. When there is any considerable loss of substance the opening is not filled in with bone save for a narrow strip around the edge. After recovery from diastasis in a child the growth of bone is not interfered with.

The Contents of the Cranium.

The Cerebral Membranes.—The tough fibrous **dura** may be divided into an outer **periosteal layer** and an inner or **supporting layer**. This corresponds to its twofold function, on the one hand as a periosteum, and on the other as a protective covering of the brain. These layers are inseparable over the greater part of their extent, but the inner separates

from the outer layer to form the *cranial sinuses* and the *processes*, like the falx and tentorium, which help to support and protect the brain (see Fig. 1).

The adhesion of the outer layer to the bone is firmer in children than in adults, but after middle life it increases with age. Hence extradural hemorrhage is rare in children. In chronic inflammation of the bone or the dura it becomes more adherent, but is less so in acute inflammations. It varies in different parts of the skull. Over the vertex and, according to Tillaux, particularly in the temporal fossæ the dura is comparatively loosely attached, except along the sutures, where it is more adherent. This loose attachment allows a probe to be passed a considerable distance between the bone and the dura, if the sutures are avoided, and large extravasations of blood or pus may occur here and lead to compression of the brain. Such extravasations are often limited to one bone by the adhesion along the suture lines, but not necessarily, especially in the case of purulent collections. The adhesion of the dura to the bone is largely due to the passage of small bloodvessels from the meningeal vessels of the former to nourish the bone. The bone can live, however, if the dura is stripped off and loss of bone is not repaired by the dura. In the majority of traumatic cases the cause of cerebral compression lies outside the dura in the epidural space or is due to the bone itself.

As pointed out by Sir C. Bell, the *dura* of the vault may be *separated from the bone* by a blow, and if this occurs during life the corresponding epidural area is occupied by a clot from the rupture of many small vessels that pass from the dura to nourish the bone. If a larger vessel is ruptured, the *hemorrhage* may gradually strip off more and more of the dura, so that a clot is formed which gradually causes local or general symptoms of *compression*. The stripping up of the dura may be demonstrated on the cadaver by striking a blow and then injecting the bloodvessels.

The vessel which by its rupture is most often (85 per cent. more or less) the *cause* of serious or fatal epidural *compression* is the **middle meningeal artery** in the temporal fossa. This is the cause of the more serious results of fracture in this region. This vessel is for the most part closely wrapped by the outer layer of the dura so that it is ruptured in any tear of the latter, in fracture of the skull. It may also be torn without fracture, for in the great wing of the sphenoid and the antero-inferior angle of the parietal it is often lodged in a bony canal or a groove whose open side is smaller than the artery, so that if by a blow the dura is here stripped from the bone the artery is torn at the point where the canal or deep groove prevents it from being stripped back with the dura. When after a blow over the position of this vessel symptoms of compression, not present at first, come on after an interval and gradually increase, rupture of this artery or some of its branches is probable. The "free interval" is due to the escape under pressure of the cerebrospinal fluid into the spinal canal, so that the hemorrhage does not seriously increase the intracranial pressure for a time. As it lies in part over or close to the cortical *motor area*, motor *paralyses* are likely to occur from local compression. As such cases commonly get progressively worse and end fatally, operation with

turning out the clot and plugging or tying the vessel is imperatively demanded.

Hence the importance of knowing the **position and course** of this vessel (see Fig. 9). The trunk of the artery passes outward and forward for a short but variable distance from the foramen spinosum, through which it enters the skull and about corresponds externally with the middle of the zygoma. It has *two main branches*, of which the larger *anterior* one runs upward and forward across the antero-inferior angle of the parietal bone and continues in a groove a little behind the coronal suture, giving off branches which run upward and backward. The *posterior branch* runs backward across the squamous bone and then upward and backward over the posterior part of the parietal bone. Although it may be possible by a single trephine opening to expose both branches of the artery, yet such an opening must be low down in the temporal fossa and below the common site of injury of the vessel, which is in the anterior branch near the pterion, where the groove is often very deep or converted into a canal. When the groove is so arranged fracture here without laceration of the artery would hardly be possible, and this thin part of the skull is particularly liable to be fractured. If we trephine and ligate the artery too low, below the point of rupture, an anastomotic branch from the orbit may join the artery above the point of ligation and thus continue the hemorrhage.

To expose the anterior branch of the middle meningeal artery a trephine opening or bone flap is made just behind the pterion (see p. 26); or two fingers' breadth above the zygoma and a thumb's breadth behind the frontal process of the malar bone (Vogt); or 3 to 4 cm. ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.) behind the latter point on a level with the supra-orbital margin; or at the intersection of a vertical line drawn through the middle of the zygoma and a horizontal line through the supra-orbital margin (Krönlein). As the artery lies enclosed in the firm dura or in the bone, the chance of spontaneous arrest of bleeding is slight.

At the *base* of the skull the *dura* is closely *adherent* to the bone, so that epidural extravasation can scarcely occur, and in fractures of the base the dura is likely to be torn, allowing the escape of cerebrospinal fluid. The dura smooths over some of the inequalities of the base and passes out through the foramina of the skull with the cranial nerves to become continuous with the nerve sheaths as well as with the pericranium on the outer surface of the skull. Along these prolongations infection may spread from the surface to the cavity of the skull. When the dura is exposed during life observe its pulsation, synchronous with the respiration and due to the rise and fall in the blood pressure of the brain during expiration and inspiration respectively. If this pulsation is absent, it indicates an increase of the intracranial pressure due to intracranial tumor, abscess, hemorrhage, etc. The sensory nerves of the dura are derived largely from filaments of the trigeminal nerve. The *inner surface* of the dura is smooth, owing to the layer of flat endothelial cells which covers it.

The Subdural Space.—The subdural space, or the potential interval between the dura and the arachnoid, contains a small amount of *fluid*

and probably serves to prevent friction between the skull and the brain during its movements, like the pleural and other serous sacs. The hemorrhage in *pachymeningitis interna* occurs in this space, into which a considerable effusion may occur without marked symptoms, on account of its wide diffusion. Following an injury extravasations of blood into this space are common, and the blood so effused is liable to shift its position and perhaps suddenly cause dangerous pressure symptoms by gravitating to the vicinity of the pons, cerebellum, and medulla. Similarly, during *operations* upon the brain, blood, pus, or irrigating fluid may enter this space and gravitate toward the medulla or spinal canal. Hence care should be taken in evacuating and irrigating cerebral abscesses to avoid the passage of the fluid into this space and to secure its escape extracranially. The subdural space communicates with the abundant lymphatics of the dura, and from the latter pathogenic organisms may invade this space. This space is continuous, through the foramen magnum, with the subdural space of the cord so that infection may rapidly spread along it in either direction. Normally, the *inner surface* of the dura is not connected with the arachnoid except by a few and very delicate processes, hence on opening the dura any adhesions which prevent the probe or finger passing freely between it and the brain are pathological.

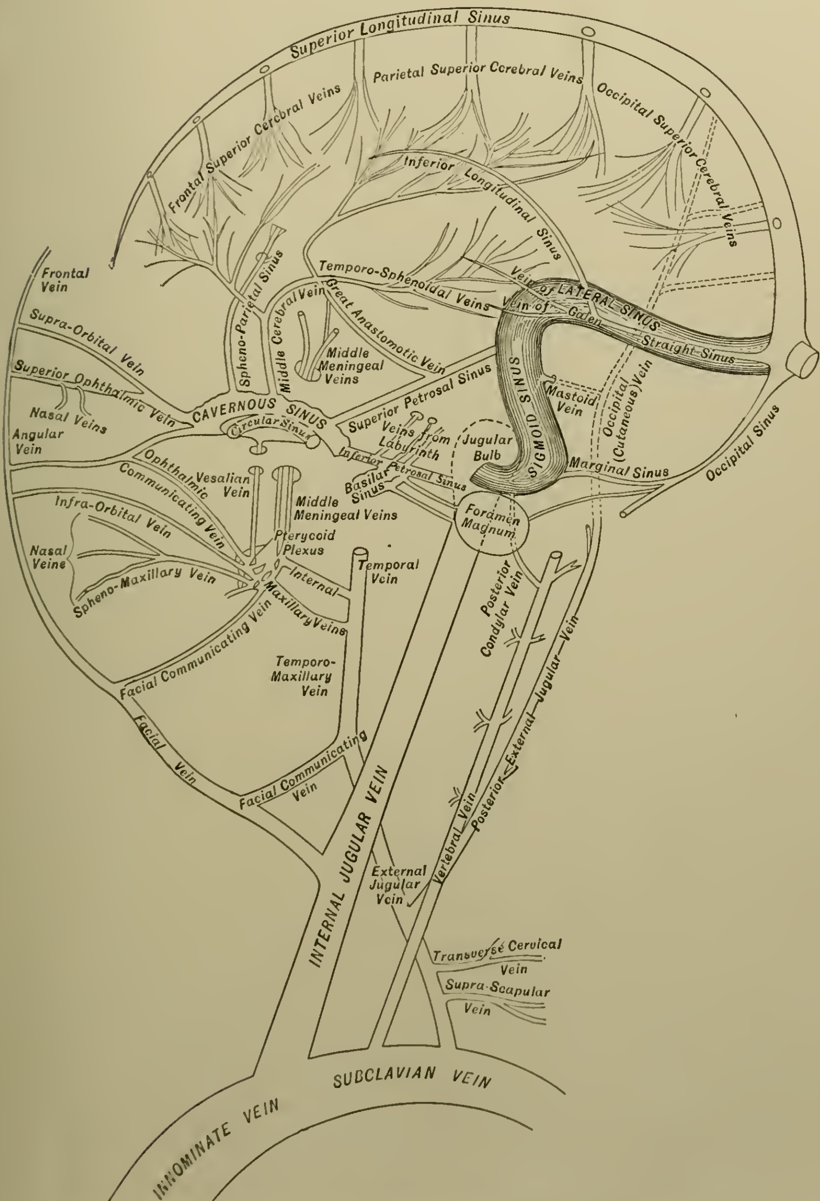
The *fibrous folds* formed by the reflection of the *inner or protective layer* of the dura (falx cerebri, tentorium cerebelli, etc.) are of little surgical interest, but they are important in preventing the compression of the two hemispheres by each other, and of the isthmus of the brain and the cerebellum by the cerebrum.

The Sinuses of the Dura.—The sinuses of the dura are formed by the separation of its inner from its outer layer on the surface or by the separation of two folds of the inner layer in the folds or processes of the dura (see Fig. 1). They are lined by an *epithelial layer* continuous with the inner layer of the veins. Their walls are rigid and *non-collapsible,* so that when wounded bleeding is not spontaneously arrested. Certain sinuses are of especial surgical interest, and their position is of importance because in certain operations we wish to avoid them, in others to expose them (see Figs. 5 and 6). Owing to their relations to the skull some of them are liable to be injured in fractures of the skull.

The **superior longitudinal or sagittal sinus** extends in the median line from the foramen cecum anteriorly to the torcular Herophili, opposite the external occipital protuberance, posteriorly. As the torcular is usually to the right of the median line, the posterior and larger part of the sinus is also rather more to the right of the median line. Through the *foramen cecum* it communicates with the veins of the nasal mucosa, hence epistaxis may directly relieve cerebral congestion, and infectious organisms from lesions of the nasal septum may thus enter the sinus. It also communicates with the scalp by the emissary veins passing through the parietal foramina, so that it may become infected from erysipelas or other septic diseases of the vertex. This sinus receives the veins from the median and upper surface of the cerebrum and communicates with the basal sinuses through the anastomosis of the superior cerebral with

the middle cerebral and Sylvian veins. As the blood of the superior longitudinal sinus usually passes into the right lateral sinus, and that

Fig. 6



Cerebral veins and sinuses, showing their communications with the extracranial veins. (From Macewen.)

of the straight sinus into the left lateral sinus, it follows that the right lateral sinus is usually the larger and receives the blood from the surface of the brain, while the left sinus drains the central ganglionic portions.

The **course of the lateral sinuses** is represented by a line from the external occipital protuberance to the upper margin of the external osseous meatus or the base of the mastoid process (see Fig. 9). It is usually slightly convex upward and crosses the asterion, from whence to the jugular foramen it is called the **sigmoid sinus**, on account of its crooked S-shaped course. The sharp downward and inward bend, or *genu*, of the sigmoid sinus on the mastoid bone is convex forward. It reaches forward to a point 3 to 12 mm. ($\frac{1}{8}$ to $\frac{1}{2}$ in.) behind a coronal plane through the posterior border of the external osseous meatus, and its upper limit is on a level with the upper part of the meatus. The genu on the right side extends slightly farther forward and outward than on the left, and this fact may possibly account for the supposed greater frequency of intracranial complications following otitis media on the right side. The genu of the sigmoid sinus receives groups of veins from the tympanum and the mastoid antrum and cells, through which infection may spread to the sinus and cause thrombosis.

The **course of the sigmoid sinus**, where it is accessible to operation, corresponds to two lines; the upper and more superficial part to the posterior $\frac{2}{3}$ of a line from the asterion to the upper margin of the external osseous meatus, the vertical part to the upper $\frac{2}{3}$ of a line from the parieto-squamomastoid junction (or the middle of the base of the mastoid) to the tip of the mastoid (see Fig. 9). An opening may be made into the genu, the part of the sinus most often affected, at a point 12 mm. ($\frac{1}{2}$ in.) behind the posterior wall of the bony auditory canal between the levels of its roof and floor. Between these levels the upper and more superficial part of the sinus is 6 mm. ($\frac{1}{4}$ in.)—sometimes as little as 2 mm. ($\frac{1}{12}$ in.)—from the surface, and is thus more superficial than the antrum, while its lower part lies more deeply.

The sigmoid sinus is connected with the surface veins through two emissary veins, the mastoid and the posterior condylar. The **mastoid vein** joins the occipital and through this the deep cervical, or occasionally it joins the posterior auricular. It may become thrombosed from sinus thrombosis, or its foramen may give vent to extradural pus in the cerebellar fossa. According to Macewen, the **posterior condylar vein** is the larger and more constant of the two, contrary to what is usually stated. It joins the deep veins at the back of the neck, and its foramen may drain extradural pus in the bottom of the cerebellar fossa, setting up a deep inflammation or abscess in the upper part of the back of the neck, which causes swelling and tenderness on pressure here. In septic sinus thrombosis these two emissary veins, as well as the occipital sinus, may convey infective matter from the lateral and sigmoid sinuses to the heart and lungs, so that ligation of the internal jugular vein does not afford complete protection against this accident.

The upper and posterior end of the sigmoid sinus lies at the junction of the middle and anterior thirds of the *cerebellum*, so that the latter

may be exposed in front of the sinus, though preferably behind it. The *parietosquamomastoid junction* corresponds to the point where the superior petrosal joins the sigmoid sinus and where the upper border of the petrous joins the mastoid bone.

The Cavernous Sinus.—The cavernous sinus, extending from the sphenoidal fissure to the apex of the petrous bone, receives and is, as it were, the continuation of the *ophthalmic veins*. The fact that the latter anastomose with the facial vein explains why an inflammation near the facial vein, like a carbuncle of the upper lip, is more serious than a similar condition on the lower lip, as the former may extend along the veins as a periphlebitis and set up a cavernous sinus thrombosis. This sinus also communicates with the *pterygoid plexus* by means of the ophthalmic and Vesalian veins, through which septic material may pass from one to the other. The intimate relation between the *carotid artery* and the cavernous sinus accounts for the fact that *arteriovenous aneurysm* has followed injury of these parts. In such cases the orbital cavity is distended with a pulsating tumor consisting of the dilated ophthalmic veins which protrude the eyeball.

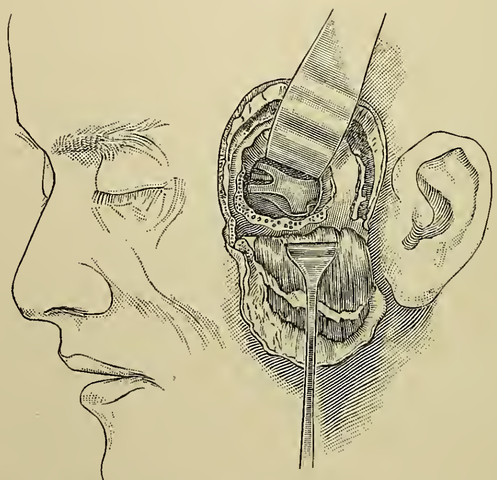
As the dural sinuses are rigid, non-collapsible, ever-patent tubes, and the jugular veins into which they empty are alternately distended in expiration and collapsed in inspiration, this *aspiration* would involve the sinuses unless there were some *mechanism to prevent it*. If the sinuses were thus aspirated and the blood of the brain suddenly propelled forward to compensate for that withdrawn, there would be a disturbance of brain function, a sudden faintness or lack of brain power on each deep inspiration. The entire sinus arrangement insures a *regular even flow* as seen in the entrance of the middle and posterior cerebral veins obliquely into the longitudinal sinus against its current, thus damming it back,[1] and especially in the *trap-like passage* of the sigmoid sinus into the jugular bulb. The roof of the lowest portion, near the end of the sigmoid sinus, is on or below the level of the floor of its entrance into the jugular bulb, and the roof of the latter is much above the whole of the lower end of the sigmoid sinus, so that an arrangement like a plumber's trap is formed to prevent aspiration of the sinus. By the entrance of the *inferior petrosal sinus* directly into the jugular bulb (so that this sinus alone, if any, would feel the effects of aspiration), and by pouring its blood into the jugular bulb from a large reservoir, the cavernous sinus, there is no absolute collapse of the internal jugular with the consequent difficulty of reëstablishing the flow.

Between the two layers of the dura, and occupying a depression on the upper surface of the apex of the petrous bone, and the adjoining cartilage filling the middle lacerated foramen, is the crescentic **Gasserian ganglion.** When the failure of peripheral operations for tic douloureux or its involvement of two or more divisions of the nerve shows extensive central involvement, this ganglion is to be removed or its sensory root resected.

[1] For further interesting particulars, consult Macewen, Diseases of the Brain and Spinal Cord, p. 35.

The best *methods of exposure* are the osteoplastic Hartley-Krause method, by which an Ω-shaped flap of bone and soft parts, having its base on a level with the zygomatic arch, is turned down, exposing the dura, or Cushing's method, in which the zygoma is temporarily or permanently resected and the skull opened at a lower level. The latter is to be preferred because it involves less danger of injury to the brain, from the pressure of the retractors, and to the middle meningeal artery. The dura is then separated from the floor of the middle fossa of the skull until the second and third divisions of the nerve are exposed and traced up to the ganglion. To expose the latter the outer layer of the dura must be divided. Its close relation to the internal carotid artery, the cavernous sinus, and the third, fourth, and sixth nerves must be borne in mind, but especially its relation to the middle meningeal artery, which enters

Fig. 7



Cushing's exposure of the Gasserian ganglion. (Kocher, after Cushing.)

the skull just behind its inferior maxillary division. The latter artery may also give trouble in the bone flap. A small vessel accompanying the inferior maxillary nerve has occasionally caused troublesome hemorrhage. As it is often a matter of great difficulty to remove the entire ganglion, the sensory root has been severed or avulsed instead. In this operation the motor root and branches of the ganglion are preserved.

The delicate **arachnoid** is closely applied to the pia over the top and sides of the head, but does not dip in between the convolutions. Over the surface of the convolutions the two membranes cannot be separated, and must be considered as one, the pia-arachnoid. The so-called **subarachnoid space,** which is a system of intercommunicating clefts partly separated by the meshes of the pia-arachnoid, is scarcely recognizable over the upper surface, though present, while over the posterior two-thirds of the base (in the posterior and middle fossæ) it is capacious and

contains the larger part of the cerebral **cerebrospinal fluid.** The latter serves as a water-bed for the important parts of the brain resting upon it, while the less important frontal lobes rest more directly upon the bone covered by dura. This arrangement of the fluid protects the posterior parts of the base of the brain from the effects of injury, either direct or by contrecoup, while the base of the frontal lobes is not infrequently injured by coming in violent contact with the irregular orbital plates. The cerebrospinal fluid differs from blood serum in its very small percentage of albumin. The cerebral and spinal subarachnoid spaces communicate freely with each other through the foramen magnum and with the cavity of the cerebral vesicles through the *foramen of Magendie* (and the foramina of Luschka), in the lower part of the roof of the fourth ventricle. Hence the cerebrospinal fluid may also serve to equalize the intracranial pressure, by being partly forced out from the ventricles through these foramina, when the nerve centres in the walls of the ventricles are congested, and down into the spinal canal if the general intracranial pressure is increased for any cause. In case these foramina are blocked by a tuberculous deposit or the pressure of a cerebellar tumor, fluid may accumulate in and enormously distend the lateral ventricles and result in internal hydrocephalus. *Lumbar puncture* as a diagnostic and therapeutic measure depends upon this intercommunication and the flow of the cerebrospinal fluid from one part to another. In operations on the base of the brain, the cord, or on a spina bifida, etc., the draining away of cerebrospinal fluid may deprive the medulla of its water-bed and cause it to rest directly upon bone, so as even to interfere with its functions.

The subarachnoid space is continued around the *optic nerve* through the orbit, where it may even become cystic by being shut off from the rest of the space. Over the other cranial nerves the arachnoid is continued only a short distance and becomes fused with the nerve sheath, but fluid injected into the subarachnoid or subdural spaces passes along the nerves as far as the limbs. Without any direct channel, fluid may also pass from the subarachnoid to the subdural space and even from the former into the longitudinal sinus, through the Pacchionian bodies, which are arachnoid villi and often project into the sinus. The arachnoid is not considered as an entity in the pathology of meningeal inflammation.

The intimate relations of the **pia** and brain, the former closely covering the surface and dipping into the substance of the brain as an investment of its bloodvessels, shows that a certain degree of encephalitis is necessary with leptomeningitis. The *lymphatics* of the pia open into the subarachnoid space.

Little need be said of the **brain** itself, apart from the facts of cerebral localization and craniocerebral topography, except that surgically it is a large soft vascular mass that does not completely fill the cranial cavity, and hence may be injured by shaking or by being thrown about and colliding with the cranial walls.

The Blood Supply.—In spite of the equalization of the circulation through the anastomosing circle of Willis, ligation of a healthy common carotid is generally followed by functional disturbances of the brain until

the collateral circulation is established, and in about 5 per cent. of cases cerebral softening and death result. Both carotids, however, have been successfully ligated in a number of cases with a considerable interval between the two operations. The effects of the heart's systole on the brain are diminished by the tortuosities of the arteries (internal carotid and vertebral) before entering the cranial cavity, but the brain *pulsates* synchronously with the systole of the heart. This pulsation may be seen or felt on the dura unless the intracranial pressure is increased, when the pulsation is diminished or absent. This pulsation may be transmitted to the overlying soft parts where the bone is wanting on account of injury, disease, or operation.

In the cerebral circulation the terminal arteries of the cortex anastomose freely, while many of the small basilar vessels, in the lenticular nucleus, internal capsule, optic thalamus, etc., derived from branches of the middle cerebral artery, have few or no anastomoses and are practically terminal. Hence when the latter are plugged by emboli, which are particularly apt to pass to these vessels, the circulation is not restored and coagulation necrosis results, from blood stasis in a cone-shaped area having its base on the surface. These same vessels are also the most common source of cerebral hemorrhage, due to the degeneration of the vessel's walls or the formation of minute aneurysms on them. Hence the frequency of capsular lesions.

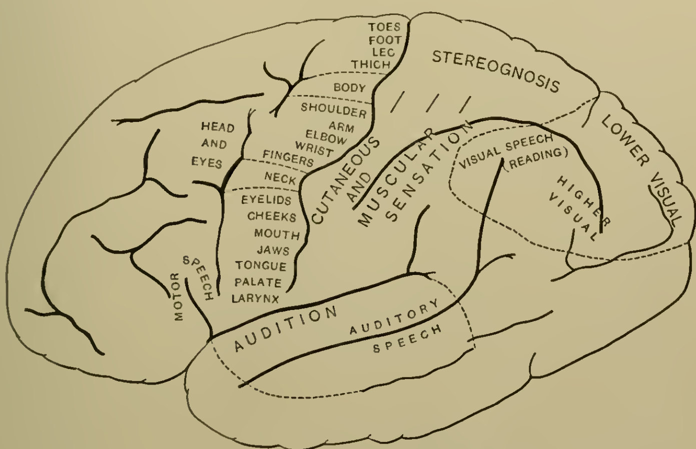
The *intracranial pressure* affects the pulse and arterial tension. With gradually increasing pressure the cerebrospinal fluid is at first displaced into the spinal canal and the veins are narrowed. As the pressure increases it impedes the circulation in the cerebral veins, and to overcome this the arterial tension is raised and the pulse is slow and full. The tension continues to rise with increasing pressure until the obstruction to the circulation in the brain is beyond the power of the heart to overcome, when the pulse becomes rapid, the arterial tension is relaxed, and collapse and death follow. We can, therefore, measure the degree of intracranial pressure by that of the blood pressure. Increased intracranial pressure may be relieved by trephining. The decompression operation of Cushing, trephining beneath the temporal muscle, is done to arrest and relieve the effects of increased intracranial pressure when a radical operation is not feasible. Wounds of the brain from injury or operative incision bleed freely, but this bleeding is readily checked. The brain weighs on an average $49\frac{1}{2}$ ounces in the male and 44 ounces in the female.

Localization of Cerebral Functions.—The cortical areas whose function is more or less accurately known comprise: (1) the *motor area;* (2) the *sensory area;* (3) the *speech areas;* (4) the *visual areas;* (5) the *auditory area;* (6) the *area of the sense of smell and taste.* The precise limit of these areas is not accurately known, and one area may digitate into another. It is most important to know the position of these centres as a guide in diagnosticating and operating on lesions of the cerebral cortex (see Figs. 6 and 7).

The Motor Area.—Before the investigations of Sherrington and Grünbaum this area was thought to comprise the cortex of the anterior

and posterior central convolutions, bordering the fissure of Rolando, and the cortex immediately adjacent to them, especially the paracentral lobule on the mesial surface. As the result of these observations on the higher apes, confirmed, in part at least, by histological studies and the faradization of the human cortex in the course of operations, the motor area is now thought to lie entirely in front of the central fissure and to extend to the bottom of it on its anterior surface only. In the upper third of the motor zone and in the paracentral lobule is the area for the **lower extremity,** in the middle third that for the **upper extremity,** and in the lower third that for the **face and tongue** (facial and hypoglossal nerves). Between the centres for the upper and lower extremities is a narrow area for the centre of movement of the **trunk.**

Fig. 8



Localization of function on the cerebral cortex; external surface. (After Starr.)

The relative situation of the centres of the several parts of the extremities and face is shown in Figs. 8 and 9, but their exact boundaries cannot be sharply defined.

The associated lateral movements of the **eyes** and the lateral movements of the **head** are controlled by the cortex of the posterior part of the second and the posterosuperior part of the third frontal convolution, irritation of which causes conjugate movements of the head and eyes to the opposite side.

The upper limit of the motor area overlaps slightly onto the mesial surface, in the paracentral lobule, where the lower part of the lower extremity may be partly represented.

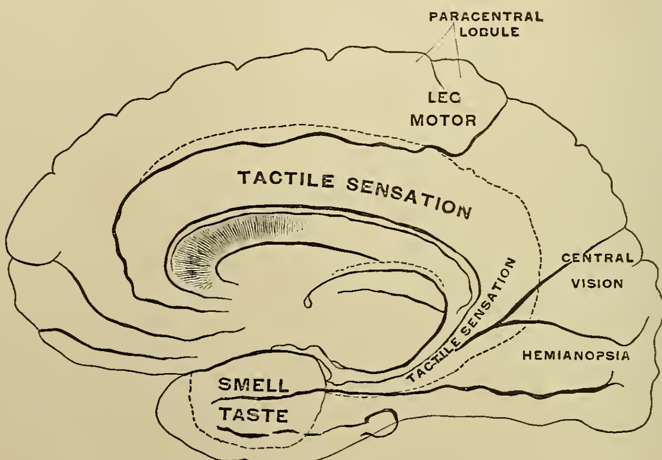
It is to be remembered that each hemisphere controls movements mainly on the *opposite side* of the body, but to a slight extent also on the same side. This accounts for a large amount of the recovery after destruction of the centres of one side, especially those of the distal movements of the limbs. This recovery is explained by others by the fact that

though there is a focus for the movement of a particular part, like the thumb, it is also represented with diminished intensity over the surrounding cortex. Hence to totally paralyze a given part a considerable amount of cortex must be excised.

The **sensory area** is in the parietal lobe. The centre for cutaneous sensibility is in the postcentral gyrus (and in the limbic lobe), that for muscular sensibility in the inferior and superior parietal convolutions and the stereognostic centre in the superior parietal convolution (Mills). These areas cannot be accurately outlined and their localization is not yet definitely established.

The Speech Areas.—The speech areas, four in number and in kind, are in the left hemisphere in right-handed persons and in the right in left-handed persons. There are two types of aphasia, which is the loss of the

Fig. 9



Localization of function on the cerebral cortex; mesial surface. (After Kocher.)

power of speech, known as motor and sensory aphasia. The **motor speech centre** lies in the posterior part of the third frontal convolution (Broca's convolution), just in front of the centre for the muscles of speech (hypoglossal and facial nerve centres). A lesion of the motor speech centre causes *motor aphasia,* in which there is a loss of the word-forming power, although the tongue is movable and the patient may understand spoken and written language and knows what he wants to say. It is as if the memory of the motor combinations essential to produce speech were lost.

The power of **writing** is usually lost with motor speech. The probable location of its cortical centre is in the posterior part of the second frontal convolution. Its loss is known as agraphia, a form of motor aphasia.

The **auditory speech centre** is in the posterior two-thirds of the first, and perhaps the second, temporal convolution. A lesion here causes "*word-*

deafness," a sensory aphasia in which the memory of the sounds of words is lost so that they are not understood, though hearing may be normal.

The **visual speech centre** lies in the posterior part of the angular gyrus in the outskirts of the higher visual or the visuopsychic field. *Word-blindness* (alexia), or the loss of memory of printed or written language, is caused by a lesion here, though sight itself may be normal.

Thus the basis of language is a series of memory pictures (1) of the sound of words; (2) of their appearance; (3) of the effort necessary to enunciate them, and (4) to write their symbols. As these memory pictures are connected with each other and with others that make up the concept by subcortical association fibers passing between them, a lesion in any of these association tracts also leads to a defect of speech. Those who have lost the memory picture have cortical word-blindness or deafness, etc.; those in whom it cannot be recalled by ordinary means, though it remains intact, have subcortical word-blindness, etc.

It may be added that Marie holds that aphasia is an intellectual deficit due to a lesion of the zone of Wernicke, comprising the areas given above as those of visual and auditory speech. Further, that aphasia is a unit and not made up of sensory and motor aphasia, and that in motor aphasia there is no lesion in Broca's convolution, but in addition to a lesion of the zone of Wernicke an involvement of the region of the lenticular nucleus.

The primary or **lower visual centre** is in the occipital lobe, especially in the vicinity of the cuneus and the calcarine fissure. Owing to the decussation of fibers in the optic chiasm, the blindness due to a lesion of this cortical centre is a homonymous hemianopsia or half-blindness of both eyes, the blind visual field being on the same side of the body in both eyes and on the side opposite the lesion.

The higher visual or **visuopsychic centre.** The visual memories of things seen are largely located in the left lateral occipital cortex in right-handed persons, and vice versa. Hence psychic blindness, or the failure to recognize objects seen, may be due to an extensive lesion of the left occipital cortex in right-handed persons, or to a lesion of both sides.

The **auditory centre** is in the middle of the first temporal convolution and the adjacent cortex. But as each centre is connected with both ears, a unilateral lesion fails to cause deafness.

The auditory memories of things heard, as well as of speech, are apparently stored on the left side in right-handed persons, and vice versa, Hence *psychic deafness,* as well as word deafness, is due to a lesion of the left temporal cortex.

The centre for the **sensation of smell** is thought to be in the uncinate gyrus, on the under surface of the temporal lobe near the tip, and the **centre for taste** is probably with or near that for smell. As each centre is related to both sides of these sensory organs, only bilateral lesions would produce loss of these senses.

A large part of the cortex is thus seen to be wanting in known function. Of this portion Flechsig has described four areas in the adult, not present in the infant, whose structure is alike, and whose time of development

differs from that of other parts. These areas lie in the frontal, temporal, and posterior parts of the parietal lobe and in the insula, and are called *mental or association centres* because they join together the activities of the various organs of sense. These and other unnamed areas of the cortex are probably related to the higher forms of intellectual activity, for the full play of which a general integrity of the whole brain is necessary. But a disease in any one of the parts does not cause the loss of any one mental faculty. Thus very considerable disease, injury, or loss of substance has involved the frontal lobes without a serious disturbance of the mental powers. It is now generally thought, however, that the location of the seat of the higher psychical functions is in the prefrontal region, more particularly that on the left side.

The function of the *corpora striata* and *optic thalami* is undetermined. Lesions of them cause no definite symptoms unless they involve the tracts in the internal capsule. The **crura cerebri, pons,** and **medulla** contain the centres of the cranial nerve nuclei and transmit the motor and sensory tracts to the cord. Hence lesions in them cause cranial nerve palsies on the same side and motor and sensory paralyses of the opposite extremities. Lesions of the crura involve especially the third cranial nerve, those of the pons, the fifth, sixth, seventh, and eighth.

Lesions of the **cerebellum,** if confined to its hemispheres, may cause no symptoms, but if in the median or vermiform lobe may produce two characteristic symptoms, a staggering gait known as cerebellar ataxia, and vertigo.

The **medulla** contains, in addition to the centres named above, many automatic centres, such as the respiratory, vasomotor, and heat-regulating centres and the inhibitory centre of the heart, also the reflex centres for deglutition, sneezing and coughing, etc.

Upon the above local symptoms we are dependent for our diagnosis of the location of a lesion. In order to be able to expose by operation that part of the brain where the lesion is thus located we must be able to locate certain of the fissures of the brain on the surface of the head.

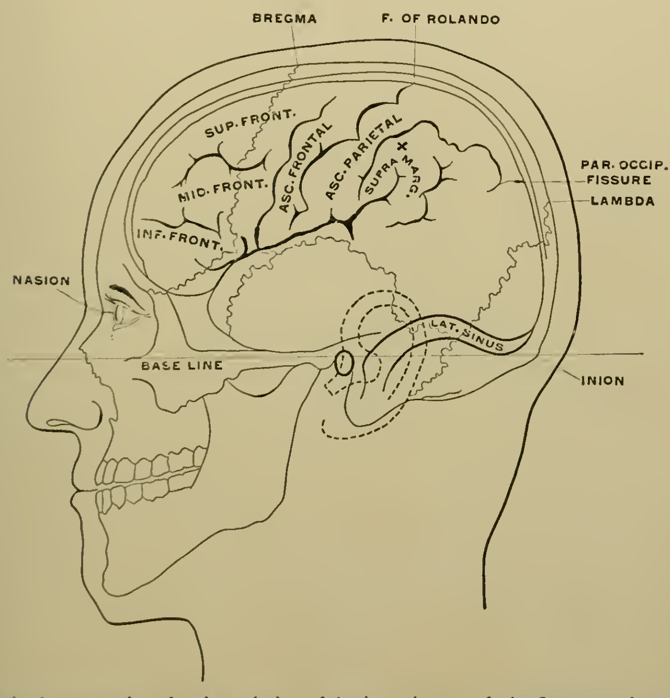
Craniocerebral Topography.—1. **The Relations of the Brain as a Whole to the Skull.**—The *lower limit of the cerebrum* is approximately indicated by a line slightly convex upward, about 8 mm. ($\frac{1}{3}$ in.) above the supraorbital margin, crossing the temporal crest 12 mm. ($\frac{1}{2}$ in.) above the external angular process of the frontal bone, thence somewhat convex downward and forward to about the centre of the zygoma, and along the upper border of this process to just above—6 mm. ($\frac{1}{4}$ in.)—the external auditory meatus, and from here to the external occipital protuberance just above the lateral sinus (see p. 38). Below the latter part of the line lies the cerebellum. Each cerebral hemisphere extends up to the superior longitudinal sinus (see p. 36), a little to one side of the median line.

2. As to the fissures, the *localization of the fissures of Rolando and Sylvius,* and perhaps also of the *parietoöccipital fissure,* enables the surgeon to expose all the cortical areas whose function is definitely known.

The Fissure of Rolando.—Measure in the median line the distance between the root of the nose (nasion) and the external occipital pro-

tuberance. 12 mm. ($\frac{1}{2}$ in.) (Thane) to 25 mm. (Kocher) behind the centre of this line (or $\frac{55}{100}$ of the distance back from the nasion) represents the *superior Rolandic point*, or the point where the continuation of this fissure meets the median line. From this point a line drawn downward and forward at an angle of 67 degrees with the median line lies over the fissure of Rolando. This angle is simply and accurately determined by folding a sheet of paper so as to divide the right angle into two equal halves and repeating the process with one of the angles of 45 degrees. Turning down or cutting off one of the resulting angles of 22.5 degrees

Fig. 10

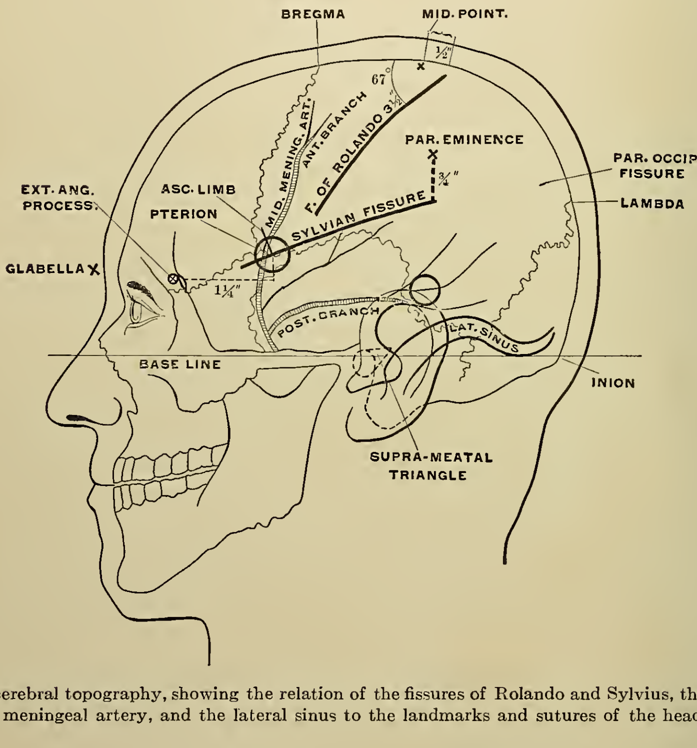


Craniocerebral topography, showing relation of brain and some of the fissures and convolutions to the sutures and bony landmarks. × indicates position of parietal eminence.

leaves an angle of 67.5 degrees. This fissure is about 8.5 cm. ($3\frac{3}{8}$) inches long and commences 12 mm. ($\frac{1}{2}$ in.) or so from the median line. In its lower third the fissure becomes a little more vertical than this line. The upper end of the fissure of Rolando may also be found by drawing Reid's base line, from the infra-orbital margin through the centre of the external auditory meatus, and erecting a perpendicular from the posterior border of the mastoid process (Reid, Krönlein). Where the latter line reaches the median line gives us the upper Rolandic point from which to draw the line as before. Or it may be drawn from this point to the inferior Rolandic point, where another perpendicular to the base line,

just in front of the external auditory meatus, intersects the fissure of Sylvius (Reid). This intersection lies on the anterior perpendicular line about 5 cm. (2 in.) above the external auditory meatus. According to Le Fort the direction of the fissure of Rolando is also represented by a line connecting the uppermost point of this fissure, as determined by either of the preceding methods, with the middle of the zygomatic arch. The *lower end* of the fissure of Rolando is about 12 mm. ($\frac{1}{2}$ in.) above the fissure of Sylvius and 2.5 cm. (1 in.) behind the junction of that fissure with its vertical limb, or about 7.5 cm. (3 in.) behind the external angular process. The lower end of the fissure of Rolando is about 28 mm. ($1\frac{1}{8}$ in.),

Fig. 11



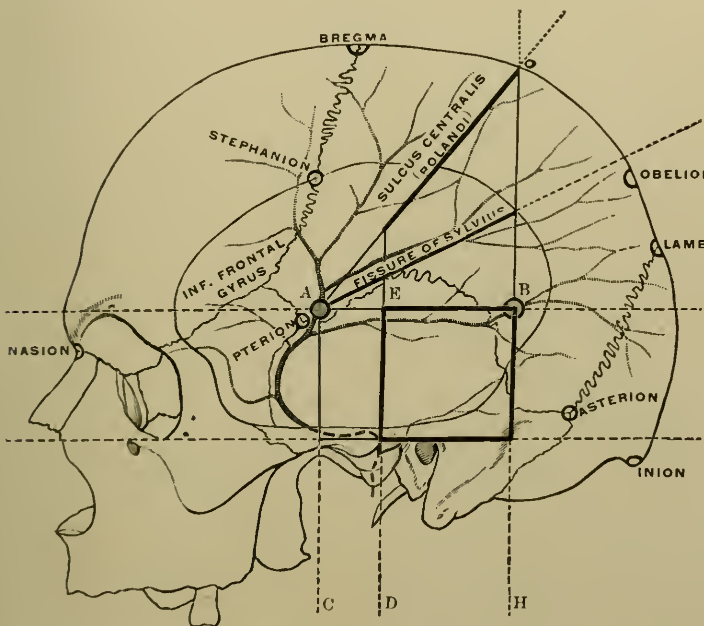
Craniocerebral topography, showing the relation of the fissures of Rolando and Sylvius, the middle meningeal artery, and the lateral sinus to the landmarks and sutures of the head.

the upper end 5 cm. (2 in.) behind the coronal suture. The upper end is about at the centre of the sagittal suture, or nearly 5 cm. (2 in.) behind the Bregma. The two central convolutions take up about 2.5 cm. (1 in.) on each side of the fissure of Rolando. In the adult, the highest part of the temporal ridge crosses the Rolandic fissure at about the junction of its middle and lower thirds, *i. e.*, between the motor areas for the arm and face.

The Fissure of Sylvius.—The main stem of this fissure meets the lateral surface of the skull at the *Sylvian point*, which is where the fissure divides into its three branches and about corresponds to the pterion. It may be

located on the surface by a point 6 to 10 mm. ($\frac{1}{4}$ to $\frac{2}{5}$ in.) vertically above the end of a line drawn horizontally backward for 3 cm. ($1\frac{1}{4}$ in.) from the external angular process. It is also at the intersection of a vertical line from the middle of the zygoma with a line drawn through the supra-orbital margin and parallel with the base line (Krönlein). The fissure of Sylvius (posterior horizontal limb) is represented on the surface by a line connecting the Sylvian point and the temporal ridge at a point 18 mm. ($\frac{3}{4}$ in.) below the most prominent point of the parietal eminence.

Fig. 12

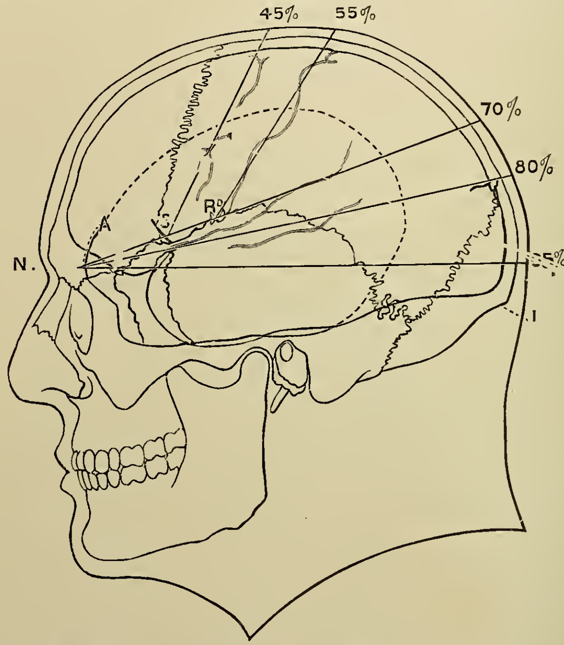


Projection of middle meningeal artery on the lateral surface of the skull. Krönlein's method of determining the position of the middle meningeal artery and the fissures of Rolando and Sylvius. *A*, Sylvian point; *O*, Rolandic point; *A C*, anterior vertical line drawn through the middle of the zygoma; *D E*, middle vertical line drawn through condyle of lower jaw; *H B O*, posterior vertical line drawn through the back of the base of the mastoid process to the median sagittal line at *O*; *A* and *B*, the points to trephine for the anterior and posterior branches of the middle meningeal artery in case of hemorrhage within. Within the rectangle below *E B* otitic brain abscesses in the temporal lobe are to be opened. The fissure of Sylvius bisects the angle between the upper horizontal line, through upper border of orbit, and the Rolandic line *A O*.

It may be more accurately represented by a line from the external angular process to a point 75 per cent. (Taylor and Haughton) or 80 per cent. (Chipault) of the distance from the nasion to the inion, or by a line bisecting the angle formed between the line through the upper margin of the orbit and parallel with the base line, and the line connecting the superior Rolandic and Sylvian points (Krönlein) (Fig. 12). The short ascending *limb* ascends for about 2.5 cm. (1 in.) just behind the lower end of the coronal suture. As the posterior hori-

zontal limb may be said to commence at this point, the 1.5 cm. or so of the Sylvian line in front of this represents the main fissure. The line representing the fissure of Sylvius is about 8.5 cm. ($3\frac{1}{2}$ in.) long, its anterior part is just above (Horsley), below, or in the line of the squamous suture. Around its hind end lies the supramarginal gyrus, to which the parietal eminence fairly accurately corresponds. Below the Sylvian fissure lies the first temporal gyrus. The anterior part of the fissure slants gently, the posterior part more sharply upward.

Fig. 13

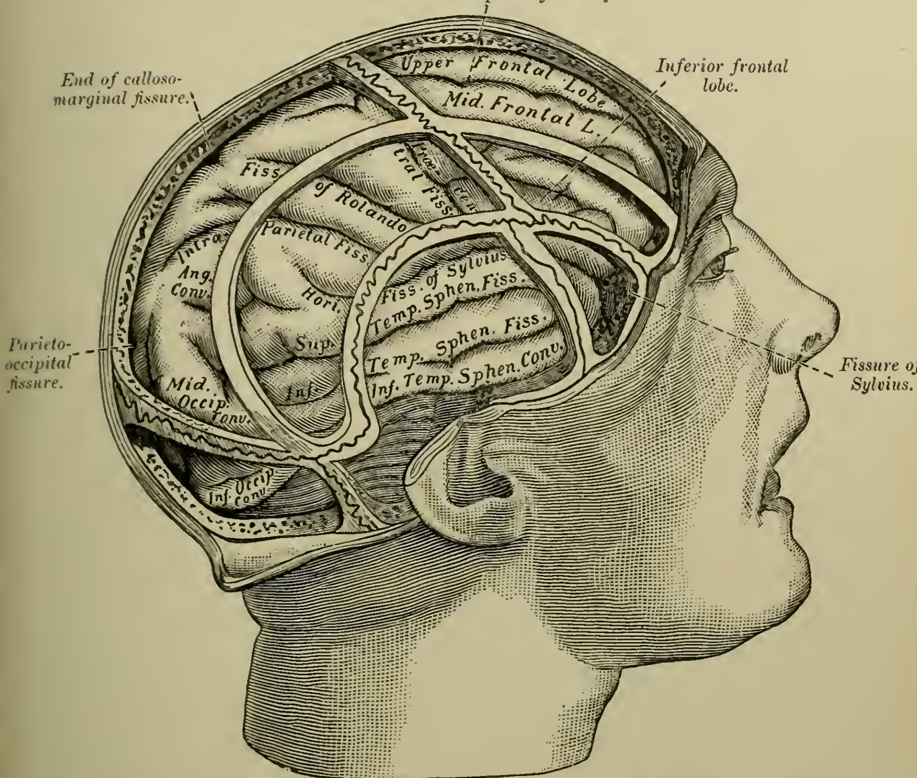


Craniocerebral topography; 45 per cent. of median naso-inionic line, pre-Rolandic point; 55 per cent., Rolandic point; 70 per cent., Sylvian line; 80 per cent., lambda; 95 per cent. gives lower edge of occipital lobe; line from *A*, external angular process, to 70 per cent. gives Sylvian fissure; *S*, Sylvian point, junction of second and third tenths of this line; R^D, inferior Rolandic point, junction of its third and fourth tenths.

The Parieto-occipital Fissure.—The parieto-occipital fissure lies 2 to 3 mm. ($\frac{1}{12}$ to $\frac{1}{8}$ in.) in front of the lambda (Horsley) or where the line representing the fissure of Sylvius, if continued, would reach the median line (or a little below this). It separates the parietal and occipital lobes, and its external limb runs outward on the external surface of the brain for about 2.5 cm. (1 in.).

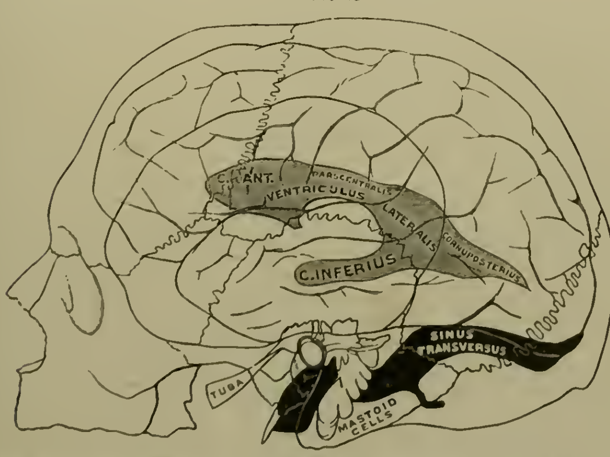
It may be added that the **coronal suture** lies over the posterior extremities of the three *frontal gyri*, the sulci separating, which may be represented as follows: *the superior* by a line drawn backward from the supra-orbital notch parallel with the median line, *the inferior* by the frontal part of the temporal ridge. The lateral ventricle may be reached by

Fig. 14



Drawing to illustrate craniocerebral topography. (Macalister.) Taken from a cast prepared by Professor Cunningham.

Fig. 15



Projection of the lateral ventricles, middle ear and lateral sinus on the side of the head.

penetrating only 1 cm. of brain tissue, through the posterior half of the first temporal convolution, 3.7 cm. ($1\frac{1}{2}$ in.) below the parietal eminence; or at the depth of 4 to 5 cm. through the superior frontal sulcus, about 5.5 cm. ($2\frac{1}{4}$ in.) in front of the Rolandic fissure. It may be drained through an opening 3 cm. ($1\frac{1}{4}$ in.) behind and the same distance above the external auditory meatus by an instrument directed toward the top of the opposite auricle and penetrating the brain for 5 cm. (2 in.), unless the ventricle is distended.

It should be remembered that the sulci and gyri are never precisely alike and that their relations to the surface vary slightly in different individuals, but as we expose a considerable area in most cases, the desired area is sure to be exposed and can be recognized by its relation to the sulci and, in the motor area, by electrical stimulation.

THE EAR.

The Pinna, Auricle, or External Ear.—The pinna, auricle, or external ear is *formed* by a partial fusion of six small tubercles on the skin at the end of the first visceral cleft. In connection with this cleft are developed the Eustachian tube, tympanum, and external meatus. A supplemental rudimentary pinna is sometimes formed at the margins of one of the lower clefts, appearing congenitally as an irregular mass of fibrocartilage on the side of the neck. When the fusion of the six tubercles is less complete than usual, a tag-like *supernumerary auricle* may be present on the cheek just in front of the ear, or *fistulæ* or *fissures* of the auricle may occur. The more marked congenital fistulæ may be due to defective closure of the first visceral cleft. A dermoid cyst of the pinna may result if the opening of such a fistula closes.

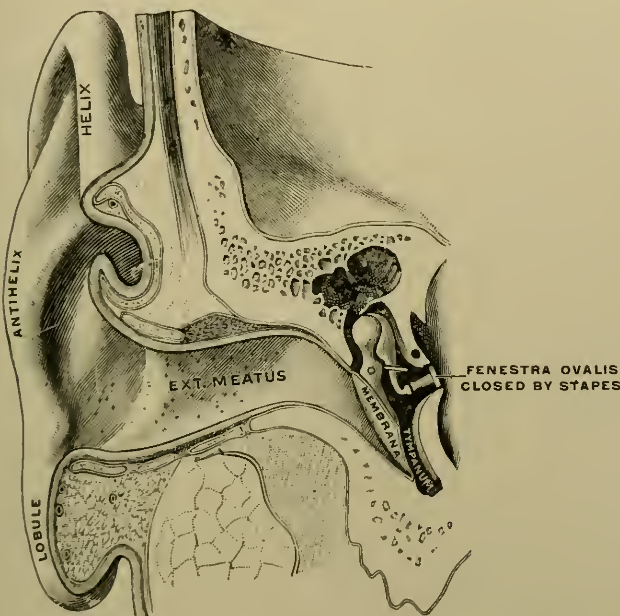
The *framework* of yellow *elastic cartilage* gives the ear its essential *shape*, which varies greatly in individuals and is largely influenced by heredity. A *hematoma* may occur between the skin and the cartilage of the ear, and is most common among athletes, such as football players, boxers, or prize fighters, and among the insane. The resulting deposit and contraction of new connective tissue, especially when the accident recurs, as in the left ear of prize fighters, causes the markings of the ear to become obliterated and replaced by a wrinkled flattened surface, a condition sometimes known as *prize fighter's ear*. Curiously enough, a fine antique bronze statue of a boxer discovered in Rome in 1885, and some other antique statues, show this same condition of the left ear.

The auricle is so *firmly attached* to the skull by the cartilaginous meatus that a body of average weight may be lifted from the ground by the ears. The removal of the pinna is followed, as a rule, by comparatively little diminution of hearing. As there is but little subcutaneous fatty tissue between the skin and the cartilage the *bloodvessels* of the ear are not well protected against cold, so that the ear is often frostbitten. As the trunk of the *posterior auricular artery* occupies the angle between the auricle and the mastoid process, we carry the *incision* to expose the

antrum or mastoid process a little behind this angle. In infants this incision should not be carried too far downward and forward, for, owing to the very small size of the mastoid, the exit of the facial nerve from the canal is unprotected and upon the lateral rather than upon the basal surface of the skull.

The External Auditory Canal.—The external auditory canal in the adult is about 3 cm. ($1\frac{1}{4}$ in.) in *length*, of which one-third belongs to the cartilaginous and two-thirds to the bony portion. In the infant the bony part is a mere ring and the canal is cartilaginous and nearly straight, which renders an examination easier. However, in the examination of

Fig. 16



Vertical section through the external auditory meatus and tympanum, passing in front of the fenestra ovalis. (Gerrish, after Testut.)

infants the auricle should be drawn downward and backward to draw away the floor of the canal from the drum membrane, with which it is in contact, owing to the obliquity of the latter. Owing to the obliquity of the drum membrane the inferior and anterior walls are longer than the superior and posterior respectively.

Its general direction is inward, forward, and somewhat downward, but in passing from without inward the outer portion slopes upward, the inner part downward so that the centre of the canal is the highest point of an upward convexity. Furthermore, the outer part inclines sharply forward and then bends backward, while the bony or inner portion inclines gently forward again. Hence in the adult, to straighten the canal so as to introduce a speculum and be able to see the entire membrane,

the pinna is pulled upward to straighten the upward curve and backward to straighten the anteroposterior curves. The external meatus, the promontory, the cochlea, and the internal meatus lie nearly in the same line.

Diameters.—The outer end is elongated vertically, the inner end slightly transversely, while the middle part is circular. On these differences depend the two forms of *ear specula,* the one round, which fits the narrow circular median part of the canal, the other oval, which fits and fills the outer part of the canal. The latter admits more light at the outer end, the former has a larger lumen where it reaches the bony portion. The osseous part is narrower than the cartilaginous, and the *narrowest part* of the canal is at the junction of the middle and inner thirds.

The cartilaginous portion of the canal has a partial *framework of elastic fibrocartilage,* continuous with the pinna. This cartilage forms but two-thirds of the circumference, is incomplete above and behind, and tails off as it passes inward to become attached to the lower third only of the margin of the osseous meatus. This attachment is by dense fibro-elastic tissue, which allows of the shifting of position of the pinna on traction. The cartilage presents clefts or fissures (*fissures of Santorini*) on the floor of the meatus, which are filled with fibrous tissue. They permit of easier movement of the cartilaginous portion and allow the spread of inflammation or of an abscess from the parotid gland below into the auditory canal, or vice versa.

The skin lining the outer part of the cartilaginous portion is supplied with numerous *hairs,* which help to keep out dust and insects, and with *sebaceous and ceruminous glands.* The former glands are often the seat of furuncles which are small but very painful, owing to the firmness of the tissues, due to the close attachment of the skin to the cartilage and periosteum. The "wax" secreted by the ceruminous or wax glands is thought to be a defence against dust and the intrusion of insects. When this wax is secreted excessively it may produce plugs, which cover the drum membrane or block the meatus, interfering with air conduction and so produce deafness, which, curiously enough, usually comes on suddenly and is continuous. The skin lining the osseous portion is thinner and only contains glands along its posterosuperior part. The skin of the meatus is liable to eczema and may become inflamed (otitis externa), giving rise to a profuse mucopurulent discharge. In addition to small furuncles, a less common but more serious and more diffuse form of infection may occur beneath the periosteum. This may spread out onto the surface of the mastoid, beneath the periosteum, or it may extend downward into the parotid region, through the fissures of the cartilage or a *gap in the floor* of the osseous portion. This gap is explained as follows. The osseous portion is largely formed by the outward growth of the tympanic ring, at first in two lateral tubercles which meet in the floor, leaving an opening mesial to their junction, which may sometimes persist. *Polypi* may grow from the soft linings of the canal and exostoses from its bony walls.

Foreign bodies are often lodged in the meatus, particularly at its inner third. They may be very difficult of extraction. More damage has been

done in many cases by blind or forcible attempts to remove the foreign body than by leaving it in place. The ear drum and tympanum have been injured in such attempts at removal, while, on the other hand, cases are reported where foreign bodies have remained in the ear from thirty to sixty years without harm. The extraction should only be attempted by means of appropriate forceps or a blunt hook, while the body is seen and the instruments guided to it through a speculum; or by means of a stream of tepid water forcibly injected through the narrow nozzle of a syringe, so as to get behind the body and force it out.

Relations of External Auditory Canal.—The relations of the external auditory canal, especially its bony portion, are of practical importance. The **superior wall** is in relation with the *middle fossa of the skull* and is separated from it by a bony plate 4 to 5 mm. ($\frac{1}{5}$ in.) thick, and sometimes thinner. Hence long-continued subperiosteal inflammation or bone disease in the canal may extend to the meninges or the brain, without necessarily first involving the tympanum. **Posteriorly** the canal is in relation with the *mastoid process* and, at its inner end, with the *mastoid antrum.* From the latter the canal is separated by a thin plate of bone, sometimes defective, so that inflammations of the one may extend to the other and inflammation in the antrum may often cause a swelling or bulging of the posterosuperior aspect of the inner end of the canal. The **inferior wall** is in relation with the portion of the *parotid gland* occupying the back of the glenoid fossa and, as stated above, a congenital gap may occur here which permits the ready extension of inflammation from the one to the other. The **anterior wall** is in relation to the *temporomaxillary joint,* and may be fractured by the condyle of the jaw in falls upon the chin. As a result of this injury there may be considerable bleeding from the ear, as also in case the drum membrane is ruptured, hence this symptom does not necessarily indicate fracture of the base of the skull. The proximity of this part to the joint helps to explain the pain of movement of the jaw when the canal is inflamed. This is also explained by the two parts being supplied by the same nerve (auriculotemporal). The relation of the cartilaginous portion to the joint is appreciated in placing the finger in the ear when one can feel the movements of the joint. Just behind the upper end of the osseous meatus is a bony prominence, the suprameatal spine. This important landmark is about 10 to 12 mm. ($\frac{1}{2}$ in.) above the floor of the antrum and usually about 1 cm. in front of the bend of the sigmoid sinus.

Nerve Supply.—The *auriculotemporal* supplies parts of the canal and the outer surface of the pinna. The *great auricular* and *small occipital nerves* also supply the pinna, while *Arnold's nerve* supplies the back of the concha and the lower and back part of the outer portion of the canal. Arnold's nerve, a small branch of the vagus, has been nicknamed "*alderman's nerve,*" from the following circumstance. It is said that diners after a heavy dinner were wont to touch the back of the ear with a napkin moistened with rose water. This is said to be very refreshing by reason of the stimulation of Arnold's nerve and thereby, reflexly, of the main branch of the vagus, which supplies the stomach.

The *irritation of the canal* by a plug of wax, the introduction of a speculum, the presence of a foreign body or of an inflammation may give rise to symptoms which are explained as **reflexes**. Thus *ear-coughing* is a reflex, through Arnold's nerve, of the branches of the vagus supplying the lungs. *Vomiting* has been caused in like manner by an irritation through Arnold's nerve of the gastric branches of the vagus. In *ear-yawning* the irritation is conveyed through the auriculo-temporal nerve to other branches of the fifth nerve which supply the muscles of the jaw. Again, other branches of the same division of the fifth nerve supply the lower teeth (inferior dental) and the tongue (gustatory), a circumstance that may account for the frequent association of earache with *toothache* or disease in the anterior two-thirds of the *tongue*.

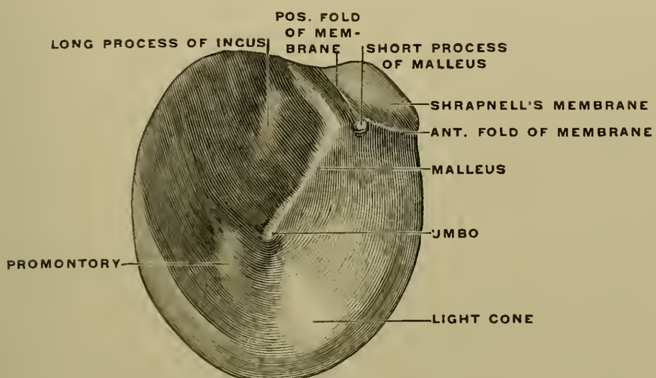
The Tympanic Membrane.—The tympanic membrane is placed so as to face obliquely outward, downward, and slightly forward. The *obliquity* with the horizontal plane is 30 degrees to 50 degrees at birth and 40 degrees to 45 degrees in the adult. According to Fick, the more vertical the membrane the more sensitive is it to sound, and it has been observed to be less oblique in musicians than in those lacking in a taste for music. Owing to the inclination of the membrane and the sloping downward of the inner end of the canal an acute-angled sinus is formed between the two, where small foreign bodies, pus, and other fluids are likely to collect. The membrane is *nearly circular* but slightly longer vertically (10 mm.) than horizontally (9 mm.). Its **shape**, however, is somewhat irregular, for above and anteriorly, where the tympanic ring is interrupted by a slight recess, the notch of Rivini, the membrane extends to the margin of the tympanum. This portion of the membrane, limited below by two small fibrous bands connecting the two angles or corners of the notch of Rivini with the short process of the malleus, bulges outward instead of inward, and is thin and lax, hence, called by Shrapnell *membrana flaccida*, and is known as *Shrapnell's membrane.* This from its thinness may be readily ruptured by a blow, and through it pus may escape from the middle ear without perforation of the membrane proper.

The *inward bulging* of the tympanic membrane is due to the position of the long process or *handle of the malleus*, which is embedded between the circular and radiating fibers of the membrane. The centre or **umbo** of this depression is slightly below the centre of the membrane and, as may be seen from either side, corresponds to the slightly flattened end of the handle of the malleus. A section of the membrane below the umbo shows this part to be slightly convex externally. When pathological products, such as mucus, pus, etc., are pent up in the tympanum, the inward bulging is diminished or even replaced by an outward one. On the other hand, when the Eustachian tube is occluded and no air can reach the tympanum, the atmospheric pressure on the outside of the membrane increases the inward bulging to such an extent that the stapes is constantly pressed inward and a ringing in the ear is produced.

The otoscopic image (Fig. 17) of the membrane as seen through an ear speculum is that of a round or *oval*, concave surface, pearl-gray in *color*, with sometimes a violet or yellowish-brown tinge and with the following *markings:* Extending from a little in front of the upper pole downward

and a little backward to the umbo is seen the *handle of the malleus.* In front of the upper end of this, and near the circumference of the membrane, is a whitish point, the *short process of the malleus.* Behind and parallel with the handle of the malleus, but less distinct and not as long, is seen the *long process of the incus.* Extending downward and forward from the umbo is the "*light cone,*" a whitish cone-shaped area of varying shape and size where the light thrown in is reflected back, owing to the inclination and curvature of the membrane. Pathologically this light cone may be wanting when a perforation occupies its position, when it is bulged outward or the surface dulled by an inflammation of the membrane. Sometimes the *chorda tympani* nerve may be seen crossing transversely near the upper end of the handle of the malleus. The *promontory* may also be seen behind the umbo.

Fig. 17



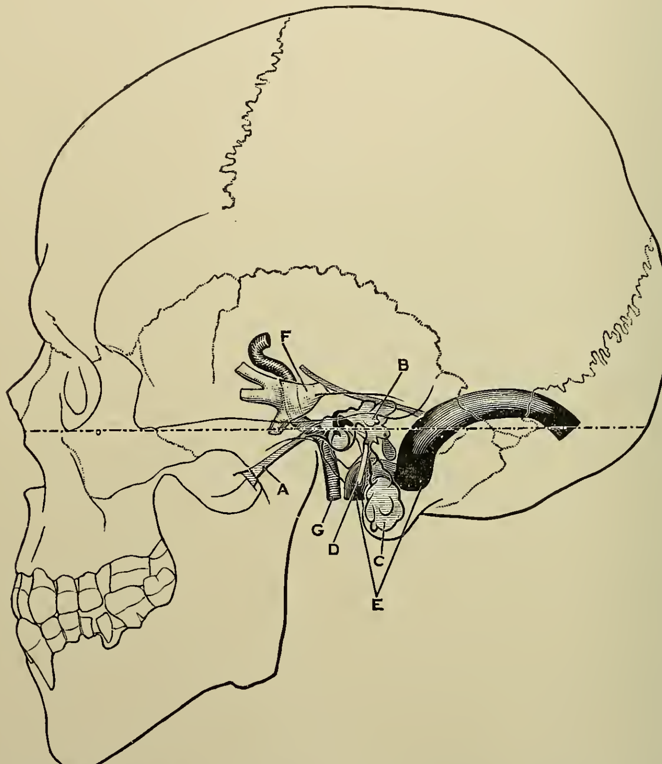
Otoscopic image of right ear drum. (Testut.)

Practically we may divide the membrane into the parts above and below the umbo. The section *above the umbo* corresponds to the ossicles, their muscles and ligaments, the chorda tympani, the foramen ovale, and the promontory. The greatest *vascularity* is in this part, the bloodvessels being especially prominent on each side of the handle of the malleus. The section of the membrane *below the umbo* corresponds to no important parts and is less vascular and less sensitive than the upper segment; hence **paracentesis** is usually practised here and for the additional reason that the lower incision affords the better drainage of the tympanum. It is noticeable, however, that the floor of the tympanum is at a lower level than the lower end of the membrane, so that perfect drainage cannot be secured in the upright position. As the **membrane consists** of a framework of circular and radiating fibers of connective tissue, covered internally by mucous membrane and externally by epidermis, it possesses *little elasticity;* hence incisions do not gape much and heal readily, often before it is desired, so that paracentesis may need to be repeated. In case of spontaneous perforation from ulceration, the wider opening resulting may heal slowly and sometimes not at all. But an opening in the membrane does not necessarily produce much deafness.

The **arteries** supplying the membrane are derived from the stylomastoid artery and the tympanic branch of the internal maxillary, the latter supplying mostly the part below the umbo, the former that above it. The *auriculotemporal nerve* supplies the membrane.

The Tympanum or Middle Ear.—The tympanum or middle ear is a narrow cleft-like cavity intervening between the external auditory canal and the internal ear. It is separated from the former by the ear drum, the vibrations of which are transmitted to the internal ear by a chain of

Fig. 18

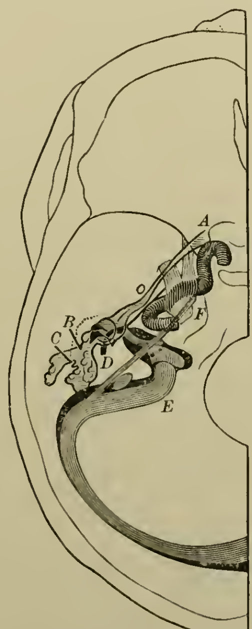


Projection of the middle ear: *A*, Eustachian tube; *B*, antrum; *C*, mastoid cells; *D*, facial nerve; *E*, lateral sinus; *F*, Gasserian ganglion; *G*, internal carotid artery, on the lateral surface of skull.

three *ossicles* which cross this narrow space. It contains *air* which reaches it from the pharynx through the Eustachian tube, and it connects posteriorly with the mastoid antrum and cells. Its *mucosa* is ciliated except where it covers the membrane, the ossicles, and the promontory, where it is thin and squamous. It measures 15 mm. ($\frac{3}{5}$ in.) in *height* and *length,* above it is 5 to 6 mm. *broad,* below 4 mm., and the umbo and promontory are only separated by 1 to 2 mm. It projects above the upper limit of the membrane, where it widens out somewhat and is called the *tympanic attic.* The cavity *lies obliquely* so that its outer and inner walls look outward, downward, and forward.

On its **inner wall**, opposite the umbo, is the *promontory*, above this the *fenestra ovalis* and below and behind the latter the *fenestra rotunda*. The fenestra ovalis leads into the vestibule and is closed during life by the stapes. In the angle between the roof and the inner wall, and appearing as a slight convexity above the fenestra ovalis, is the *facial canal* (aqueductus Fallopii) transmitting the facial nerve. The wall of this canal is very thin, especially in infants in whom it may be defective. This fact accounts for *facial paralysis* in the course of chronic otitis media, particularly in children.

Fig. 19



Projection of the middle ear: *A*, Eustachian tube; *B*, antrum; *C*, mastoid cells; *D*, facial nerve; *E*, lateral sinus; *F*, Gasserian ganglion, on the base of the skull.

The *floor* of the tympanum is like a narrow gutter below the level of the ear drum, and hence drainage of the tympanum is not perfect after paracentesis of this membrane. The floor is only separated from the *jugular and carotid fossæ* by a thin plate of bone, and fatal hemorrhage from the carotid has followed necrosis of this bony plate.

The **outer wall** consists chiefly of the *membrane*, but is partly osseous and presents the apertures of entrance and exit of the *chorda tympani nerve*, which lies beneath the mucous membrane of this wall. This nerve crosses the upper part of the membrane internal to the handle of the malleus. If affected in connection with otitis media, its irritation causes prickling of the end of the tongue; its destruction, unilateral loss of taste in the anterior two-thirds of the tongue.

The **roof or tegmen** tympani is a very thin layer of bone which separates the tympanum from the *middle fossa of the skull* and the temporosphe-

noidal lobe. *Defects* are sometimes found in the tegmen, so that in cases of otitis media inflammation may spread from the ear to the meninges or the brain by direct extension through such defects or after necrosis of the thin bony plate, or indirectly along small veins passing through the tegmen to the sigmoid and superior petrosal sinuses. In most otitic brain abscesses the bone is diseased directly to the dura.

The **petrosquamous suture** forms the outer boundary of the tegmen, the eminentia arcuata over the superior semicircular canal and the groove leading to the hiatus Fallopii form the inner boundary. The suture is generally obliterated by the end of the twelfth year, before which time inflammation may readily spread through the suture membrane from the tympanum to the meninges. The suture not infrequently remains open longer. **Fracture of the tegmen** and rupture of its closely adhering membranes causes an escape of cerebrospinal fluid into the middle ear. The tegmen is continuous with the roof of the antrum behind, and slopes downward in front to become continuous with the roof of the Eustachian canal.

The **posterior wall** at its upper end, on a level with the tympanic attic, presents the irregularly triangular *opening into the antrum,* and below this there are sometimes smaller openings directly into the mastoid cells.

As the result of chronic inflammatory changes the *joints of the ossicles* may become *stiffened,* so that they do not readily transmit slight vibrations. It is in such cases of partial deafness that the hearing is better in a noisy place, like a crowded street or a railway train, for the resulting vibrations are sufficient to set the ossicles in vibration and the additional vibrations, due to the voice, are more readily transmitted to the internal ear. When the malleus and incus are removed and the membrane is freely perforated, a considerable degree of hearing may be retained, the vibrations being transmitted directly to the stapes through the aperture in the membrane. The tympanum communicates with surrounding parts by many apertures, both large and small, through which pathological processes may extend in various directions.

The Mastoid Antrum.—The mastoid antrum, variable in size, but about as large as a pea, lies behind the attic of the tympanum into which it opens. The *passageway* is frequently on a higher level than the floor of the antrum, so that drainage into the tympanum from the antrum is not well provided for, and fluid is apt to gravitate into the mastoid cells which communicate with it. As the *facial canal* descends on the *inner wall* of this passageway, one must keep to the outer wall of the passage in operations, in order to avoid the nerve. It follows also that the antrum lies behind the facial nerve.

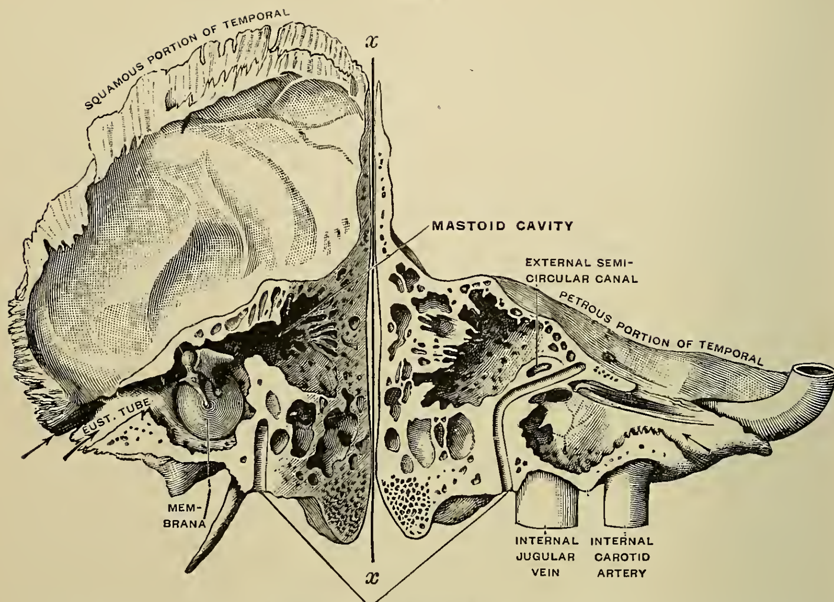
The *antrum lies* nearer the outer surface of the skull than the tympanum, and is covered externally by the *descending plate of the squamous bone,* between the temporal ridge and the squamomastoid suture. This plate may present defects at birth, exposing the antrum. The *squamomastoid suture,* which is wide in infancy, persists frequently until puberty, occasionally through life, and traces of it are also found in the adult in the shape of foramina, through some of which minute veins pass out

from the antrum and tympanum. Inflammation travelling along these veins may set up a periostitis on the mastoid. So long as this suture remains unossified inflammation may spread and pus find a free outlet to the surface from the tympanum antrum, an occurrence not infrequent in children.

Operations confined to this plate of the squamosal, *i. e.*, above the squamomastoid suture, are safe as regards injury to the sigmoid sinus or the facial canal. Roughly speaking, the *level of the antrum* corresponds to that of the upper half of the external osseous meatus, and the passage between the tympanum and the antrum corresponds to the postero-superior quadrant of the meatus. Hence the **operation of opening the antrum** is commenced in the bone just behind this quadrant, where Macewen has pointed out the existence of what he calls the **suprameatal triangle.** This occurs in 99.5 per cent. and is well-marked in 94.6 per cent. of cases. It is usually a depressed area, sometimes a slightly prominent one. It is *bounded* above by the posterior root of the zygoma, below by the posterosuperior quadrant of the external meatus, and behind by a vertical line drawn tangent to the posterior border of the meatus. The *opening* is to be made at the latter line, the base of the triangle, and is to be carried inward, with a slight inclination forward, parallel with the bony external auditory canal, the direction of which may be determined by a probe passed into it posteriorly between the skin and the bony wall. At this point of entrance the *outer wall* of the antrum is about 2 mm. *thick* in the infant, 1 cm. at nine years (Symington), and $1\frac{1}{2}$ cm. ($\frac{3}{5}$ in.) or less in the adult, while the *inner wall* averages 18 mm. ($\frac{3}{4}$ in.) from the surface in the adult. The opening to reach the antrum should not be carried deeper than this for fear of injuring the facial nerve. Hence in infants pus in the antrum can readily reach the surface or be readily evacuated by operation. As the increase of growth of the mastoid involves principally the outer part, the antrum becomes more and more deeply placed.

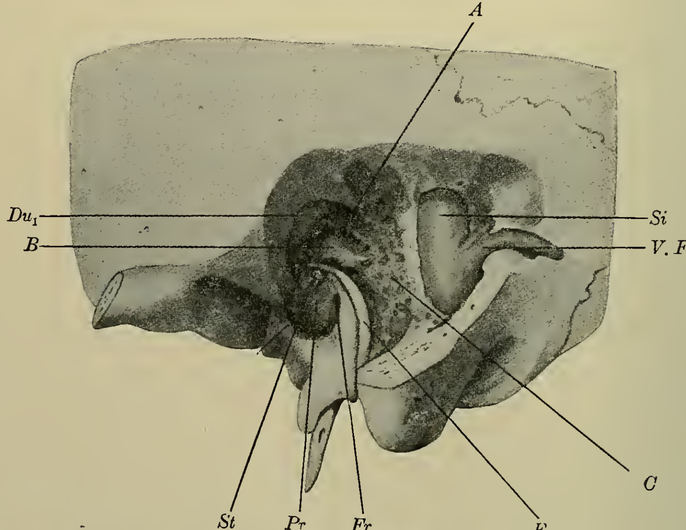
The other **relations of the antrum** are of great importance in case of inflammation extending into this cavity or of operations to evacuate the pus. Such inflammations readily extend into the antrum from the tympanum on account of the free opening between them and the continuity of their lining mucosæ. The *mucosa* of the antrum is thin and not ciliated. The **roof** or tegmen antri is a very *thin plate* (about 1 mm.) of bone continuous with but at a little higher level than the tegmen tympani. Inflammation may readily extend through this thin roof to the meninges, causing meningitis, or into the neighboring brain, causing an abscess of the temporosphenoidal lobe or of the cerebellum. The lower border of the posterior root of the zygoma indicates the *level of the roof* of the antrum, or it may lie a little above it. A few millimeters above this is the base of the brain. That part of the **anterior antral wall** separating the antrum from the inner end of the external auditory canal is thin and sometimes defective (see p. 55). **Postero-internally** the antrum is in close relation with the *sigmoid sinus*, 5 to 7 mm. ($\frac{1}{5}$ to $\frac{1}{4}$ in.), intervening in the infant. The *rear* of the antrum may be freely and safely exposed as far as its outer covering by the descending plate of the squamous extends

FIG. 20



Coronal section of the right temporal bone, passing through the Eustachian tube and the middle of the tympanum. Both surfaces of the section are shown, the parts being hinged on the line xx. (Gerrish, after Testut.)

FIG. 21



Mastoid process of an adult opened to expose and show the relations of the antrum, facial nerve, sigmoid sinus, etc.: *Du*, dura of middle fossa; *A*, antrum; *Si*, sinus; *V. F*, mastoid emissary vein; *C*, mastoid cells; *F*, facial nerve; F_1, fenestra ovalis; *Pr*, promontory; *St*, stapes; *B*, horizontal semicircular canal.

Development.—The *antrum* is present and nearly of full size at birth, while the *mastoid cells* are developed later. The *mastoid process* is present at birth, but does not become pronounced externally until about the second year, and it continues to grow for many years. The *mastoid cells* are developed with the process, but at first are like spaces of cancellous bone; the true air cells do not appear until after puberty. The cells of the mastoid continue to enlarge and extend well into adult life, when they may reach superiorly within 12 mm. ($\frac{1}{2}$ in.) of the squamoparietal suture, anteriorly over the external meatus, posteriorly to the mastoöccipital suture, and rarely beyond it.

The antrum is surrounded by **mastoid cells** on all sides but its roof. Most of the mastoid cells open directly or indirectly into the antrum and are lined by a mucosa continuous with and similar to that of the antrum, hence in inflammation of the latter the former are secondarily involved. *Suppurative inflammation* of the mastoid antrum and cells is one of the most important complications of middle-ear disease. Some of the more distant inferior cells are diploic spaces filled with red marrow, and have no direct connection with those above, but in case of inflammation the thin septa between may become disintegrated.[1] *Internally* the mastoid cells come in very close relation to the *sigmoid groove.* Only a thin osseous layer separates them, and occasionally this is defective. As this layer is perforated, opposite the sigmoid bend, by minute veins leading from the mastoid antrum and cells to the sigmoid sinus, thrombosis of the latter may result from inflammation in the former. In cases where the outer surface of the mastoid is perforated, as the result of a fracture, or a congenital, or pathological loss of substance, emphysema may occur and form a tumor-like bulging (*pneumatocele*) over the mastoid, the air coming from the mastoid cells.

The Eustachian Tube.—The Eustachian tube, connecting the tympanum with the nasopharynx, measures 3.5 cm. ($1\frac{2}{5}$ in.) in **length** in the adult and half of this in the infant, in whom it is also wider. Its **direction** is forward, with an inclination of 45 degrees inward and 40 degrees downward in the adult, while in the infant its downward inclination is only 10 degrees. These facts explain the readiness with which inflammation spreads from the pharynx to the middle ear and pus or injected fluid in the middle ear escapes into the pharynx. As the tube is shorter, wider, and more horizontal in *infants* and young children, inflammation spreads more easily from the pharynx to the tympanum in young subjects. The *tympanic orifice* of the tube is on a level with the roof and inner wall of the tympanum and, as it is on a higher level than the floor, it does not serve well for drainage. A straight instrument passed through the tube and on through the tympanum would strike the joint between the incus and stapes and pass into the antrum.

In the adult the posterior *one-fourth* of tube is *bony,* the rest is cartilaginous, the point of junction, the isthmus, in the petrosquamous angle,

[1] According to Zuckerkandl the mastoid cells are entirely air cells in 36.8 per cent., entirely diploic in 20 per cent., and partly air and partly diploic cells in 42.2 per cent. of all cases. In rare cases the cells are absent and the bone is dense and sclerosed.

being the narrowest part of the tube. A bougie $1\frac{1}{2}$ mm. in diameter will readily pass the isthmus of a normal tube. At the same point the tube bends slightly, though for practical purposes it may be regarded as straight. In the middle of its course it lies close to and parallel with the carotid artery, which is internal to it. The *lumen* of the bony portion is always open, that of the cartilaginous part is only open when the palate is raised during the act of swallowing, etc., when air may pass from the pharynx to the tympanum and equalize the atmospheric pressure on the two sides of the drum membrane. When the tube is *obstructed,* as by inflammation or a thickening of the mucosa or by pressure upon its pharyngeal orifice, the pressure on the outside of the membrane is in excess, so that the latter is thrust inward and presses the stapes against the fluid of the vestibule, which causes an annoying buzzing or singing. If the obstruction is but slight, the singing may cease after an act of swallowing, or, failing in this, by a forcible expiration while the nose and mouth are kept closed (*Valsalva's method*), or by forcibly inflating the nose and nasopharynx by a rubber air-bag whose outlet is held in one nostril while the patient swallows a mouthful of water as the bag is compressed (*Politzer's method*), or, finally, by inflation through a *Eustachian catheter* passed into the pharyngeal orifice of the tube.

These phenomena are readily explained by the *anatomical structure* of the cartilaginous part of the tube which is made of a plate of cartilage folded on itself, the two borders of which are joined by fibrous tissue on the outer aspect of the tube to complete the lumen. To this fibrous portion are attached fibers of the tensor palati and palatopharyngeus, so that in swallowing or any act involving the elevation of the palate, the tube is opened by their pulling the fibrous portion away from the cartilaginous portion. Advantage is taken of this by artillerymen, who hold open and breathe through the mouth when a loud report is expected. When we breathe through the open mouth the palate is kept elevated, and, consequently, the Eustachian tube is kept open, so that the vibrations of the air on the membrane may be equalized by reaching it from both sides. Thus not only the painful shock of the loud report is avoided, but even the danger of rupturing the membrane.

The trumpet-shaped **pharyngeal orifice**, the largest part of the tube, is vertically elongated and is marked by a prominent ridge above, in front and behind. Its **position** is about at the *centre* of the lateral aspect of the *nasopharynx,* its upper border being about equidistant and 12 mm. ($\frac{1}{2}$ in.) from the roof of the pharynx above, its back wall behind, the level of the palate below, and the end of the inferior turbinate bone in front (Tillaux). It lies nearly directly above the posterior margin of the aponeurosis of the soft palate and looks downward, inward, and forward. At birth it is at or below the level of the palate.

With a knowledge of its position, and remembering that it is bounded above and at the sides by a projecting cartilaginous rim and is open below, we pass a **Eustachian catheter** in one of several ways: (1) After passing it through the inferior meatus of the nose with its beak downward until it touches the posterior wall of the nasopharynx, the beak is turned

outward and the catheter is slowly withdrawn about 1 cm. until it is felt to glide over the projecting posterior rim of the opening, when it is turned still farther, until the beak and the ring on the handle point to the outer canthus of the eye. (2) After reaching the posterior wall of the nasopharynx the beak is turned inward and the catheter withdrawn until its beak catches on the posterior border of the nasal septum, when the catheter is rotated through a semicircle so that the beak, gliding over the upper surface of the soft palate, enters the Eustachian orifice on its lower or open side. The curve of the catheter is such that when the curved portion catches on the septum the tip will be far enough behind the margin of the hard palate to enter the Eustachian orifice. We may also withdraw the catheter with its beak down until the latter catches on the posterior margin of the hard palate and then rotate outward through 90 degrees, but this plan is not so sure on account of the difficulty of distinguishing between the posterior margins of the hard palate and of the aponeurosis of the soft palate.

Just behind the prominence caused by the pharyngeal orifice is a depression in the wall of the pharynx, the **fossa of Rosenmüller.** This may be mistaken for the opening of the tube, for it may readily engage the tip of the catheter, and it is the principal cause of error in passing the catheter. When the catheter is in Rosenmüller's fossa, the patient gives a sudden start when air is forced through it, but when the catheter is in the Eustachian tube the surgeon can hear the entrance of air into the ear by means of a tube passing between the patient's meatus and his own. This fossa is greatly deepened when the pharyngeal (Luschka's) tonsil, internal to it, is enlarged.

In cases of *deafness* associated with *hypertrophy of the tonsil,* which lies below the soft palate, the obstruction of the tube is not due to the pressure of the enlarged tonsil itself, but to the associated hypertrophy of the adenoid tissue about and within the orifice of the tube. The hypertrophied tonsil may hinder the opening of the tube by pressing up the palate and thus relaxing the tensor palati muscle. The movement of the *cilia* of the epithelium which lines the tube is toward the pharynx. The **lymphatics** of the external and middle ear and of the Eustachian tube enter nodes near the angle of the jaw.

THE FACE.

Region of the Orbit and Eye.

The Eyebrows.—The eyebrows are composed of layers similar to those of the scalp except that the subcutaneous layer contains but little fat and the muscular layer includes three intersecting muscles, the corrugator supercilii, the occipitofrontalis, and the orbicularis palpebrarum muscles. *Incisions* made here should be parallel to the long axis of the eyebrow so that the cicatrix may be hidden in the hairs. Blows or falls may produce a *wound* made by the supra-orbital margin cutting through from

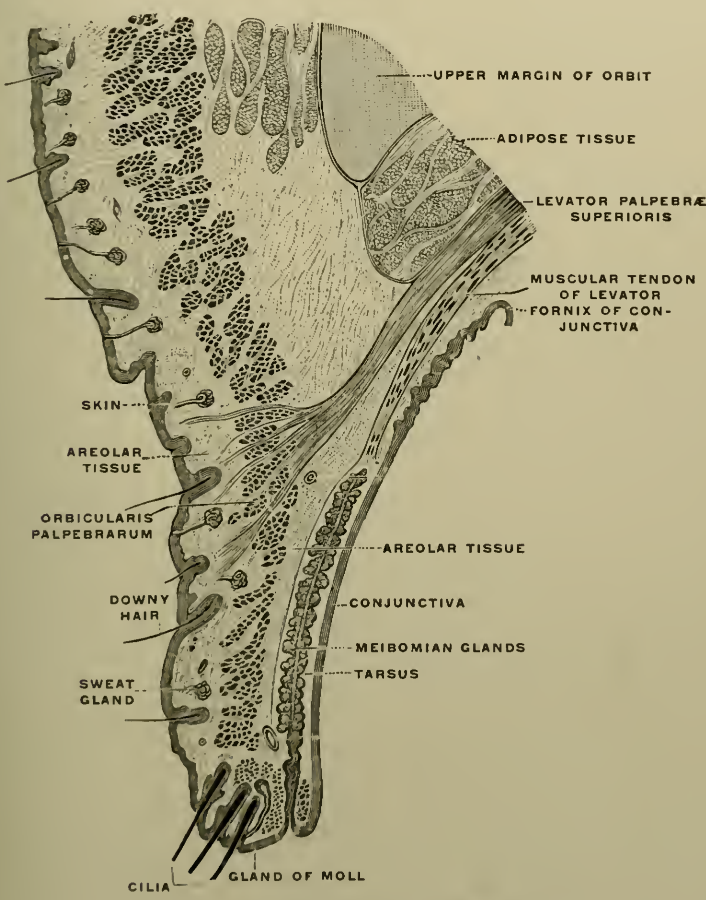
within and often appearing like an incised wound. The eyebrows, especially their inner end or head, correspond to the *frontal sinuses.* The outer end or tail of the eyebrows, at the level of the external angular process, is a favorite situation for small *dermoid cysts,* which are here due to a portion of skin being included beneath the surface in the closure of the outer end of the orbitonasal fissure. Such cysts may occur at other points along this fissure. They are beneath and do not involve the skin and often indent the bone. The *hairs* of the eyebrows help to shade the eyes, to protect them from dust, and to deflect the perspiration of the forehead beyond their limits. The corrugator muscle is supplied by the *facial nerve* and is affected in facial paralysis. The *lymphatics* of the outer half run to the parotid nodes, those of the inner end to the submaxillary nodes.

The Eyelids (Fig. 22).—The eyelids serve to cover, protect and keep moist the eyes. Examining the component layers successively, we find that (1) **the skin** is very thin and delicate so that extravasation of blood beneath it shows through as a "*black eye*" almost at once. It presents numerous transverse *folds,* in line with which all *incisions* in the lid should be made. These folds are most marked beyond the tarsal cartilages, and in the upper lid one deeper than the rest (*superior palpebral fold*) divides the lid into two parts, a lower smoother tarsal portion covering the globe, and an upper more wrinkled orbital portion covering the soft parts of the orbit. The folds of skin are due to its laxity and its loose attachment to the muscular layer by (2) a thin layer of **fatless connective tissue.** The *laxity of the skin* makes it well adapted for *plastic operations.* By reason of its loose attachment it is readily affected by the traction of cicatrices below the lower lid, which draw the latter away from the globe and thus produce *ectropion* or eversion of the lid. *Epithelioma* frequently attacks the lids and may in time produce ectropion. The skin contains some *pigment,* which helps to protect the eye from bright light, and the yellowish plaques sometimes seen in the skin in old people, especially near the inner canthus, are due to an accumulation of sebaceous matter in the numerous sebaceous glands.

3. The **orbicularis palpebrarum,** or sphincter muscle of the lids, by its *action* closes the lids, raising the lower and depressing the upper one. As it is attached internally to the firm tendo oculi, its contraction draws inward the outer commissure, which is attached externally by the less firm external tarsal ligament. This inward motion of the eyelids helps to wash the lacrymal secretion toward the inner canthus and the puncta lacrymalia and to clear the eye of dust. The muscle is supplied by the *facial nerve,* in paralysis of which the ability to wink or close the eyelids is lost. Hence the importance of sparing this branch of the nerve in any peripheral operation for tic douloureux if the operation on the ganglion may be subsequently demanded, for this operation anesthetizes the conjunctiva (see foot note, pp. 68 and 78). The contracture of the muscle (*blepharospasm*) closes the lids continuously, and may reach such a degree as to invert the free border of the lids (entropion), the pressure of which may occasion ulceration of the cornea.

4. Separating the muscle from the tarsal cartilages is a thin, loose **connective-tissue layer.** This is readily *infiltrated* by edema, inflammatory or bloody exudation, etc., which cause a rapid and considerable swelling of the lids. In the puffiness of the lids so common in Bright's disease and some other conditions the swelling is largely in this layer. This layer also includes fibers from the fibrous expansion of the levator palpebræ muscle in the upper lid and of the corresponding rectus muscle in both lids.

Fig. 22



Upper lid in sagittal section. (After Merkel)

5. The stiff plates of closely felted connective tissue called the "**tarsal cartilages**" form the framework of those parts of the lids which cover the globe. The opposing *margins* are free, except internally and externally, where they unite to form the *canthi*, the outer margins are connected with the periosteum at the margin of the orbit by the *palpebral fascia*. The latter covers the soft parts of the orbit and is firm enough to prevent

an extravasation within the orbit from reaching the surface of the eyelids. The *breadth* of the upper tarsus (10 mm.) is about double that of the lower, and opposes the examination of the inner surface of the upperlid, while the inner surface of the lower lid is readily exposed by drawing down that lid. To *expose* the inner surface of the *upper lid,* as in the search for foreign bodies, we direct the patient to look down, and then seize the eyelashes and the edge of the lid and evert it by raising up the free border while the middle of the lid is pressed down by a match, small pencil, etc. Attached to the upper border of the upper tarsus, and its anterior surface just below this point, is the *levator muscle* which raises this lid. As it is supplied by the *third nerve,* this lid droops (*ptosis*) when that nerve is paralyzed. Incisions to reach the cavity of the orbit are made beyond the limits of the tarsi, through the palpebral fascia, usually that of the upper lid. The two tarsi, where they join internally and externally, are connected with the inner and outer orbital margins by the *palpebral ligaments.* Of these, the inner, **tendo oculi**, is attached by two limbs to the two ridges bounding the lacrymal groove, and thus embraces the lacrymal sac, to which it is an important guide. It lies in front of and external to the *lacrymal sac* at the junction of its middle and upper thirds and can be made prominent by drawing the lid outward.

6. The **conjunctival mucous membrane** adheres closely to the back of the tarsi (*palpebral conjunctiva*). This part of it is thick, red, and vascular, and its degree of redness, in the absence of inflammation, is taken as an indication of the presence or absence of anemia. In the eye method of the tuberculin diagnostic test the same sign indicates that the patient has a tuberculous process. In *granular lids* the little elevations known as granulations are due to nodules of adenoid tissue, enlarged mucous follicles, and papillæ. From the contraction of the new connective tissue found abundantly in the membrane in such conditions the conjunctiva is puckered and the edge of the lids may be inverted (*entropion*). A similar result follows from the specific chronic conjunctivitis known as trachoma. The rich sensory *nerve supply,* from the ophthalmic division and the infra-orbital branch of the fifth nerve, explains the exquisite *pain* caused by conjunctivitis or the presence of a foreign body.[1]

The conjunctiva is reflected from the back of the lids onto the surface of the globe, the anterior third of which it covers, up to the edge of the cornea.

The point of this reflection is called the **fornix**. The *upper fornix* is the deeper, extending above the corresponding tarsus to the junction of the inferior three-fourths with the superior fourth of the upper lid. Hence *incisions* to reach the orbital contents are made in the upper fourth of the lid so as to avoid the conjunctiva. The *external canthus* is several millimeters from the outer margin of the orbit and the conjunctiva extends beneath the lids here as an *external* cul-de-sac or *fornix.* It is in one of the cul-de-sacs, superior, external, or inferior, that *foreign*

[1] After the operation of *removal* of the *Gasserian ganglion* the loss of sensation of the conjunctiva renders the presence of dust and foreign bodies painless, but at the same time the latter set up an inflammation of the conjunctiva, so that the eye may have to be kept closed and protected.

bodies are likely to be lodged. To discover and remove such bodies the inferior and external fornices can be readily explored by drawing the lids downward or outward respectively, while the upper fornix may be explored by everting the lid as described above, or the foreign body may often be removed by pulling down the upper lid so that its inner surface is wiped off on the outer surface of the lower lid. At the **inner canthus**, which reaches to the inner margin of the orbit, is an island of modified skin, the *caruncle*, and external to this the conjunctiva presents a small vertical *semilunar fold*, the homologue of the third eyelid or membrana nictitans of birds.

The conjunctiva covering the globe (*ocular conjunctiva*) is *thin* and loosely attached so that it is freely *movable*. This permits of free movement of the ball and is of great value in some operations. Some of the *vessels* seen through the ocular conjunctiva belong to the underlying sclerotic, as can be shown by their remaining stationary when the conjunctiva is moved over them. This part of the conjunctiva has but little vascularity, unless it is inflamed, so that the white color of the sclerotic shows through it. The *looseness* of the *subconjunctival tissue* over the globe favors the development of *edema*, which may reach such an extreme degree that the eye cannot be closed, and the cornea is partly or entirely covered. It also favors the occurrence of subconjunctival ecchymoses which may be due to the giving way of one of the poorly supported vessels, as in severe vomiting or a paroxysm of whooping cough, or to an extravasation, as from a fracture of the base of the skull involving the orbital roof. One peculiar feature of subconjunctival ecchymoses is the fact that they retain their scarlet color, owing to the thinness of the conjunctiva which allows the air to reach the blood and keep it oxygenated. Although the conjunctiva is normally very thin, it may hypertrophy in the form of a vascular triangle (*pterygium*), the base of which is directed toward one of the canthi, the apex to and finally over the pupil.

The **arteries** of the eyelids, derived from the lacrymal and palpebral branches of the ophthalmic, form arches near the free borders of the tarsi in the connective-tissue layer beneath the muscle. The veins enter into branches of the ophthalmic veins at the outer canthus and into the veins of the face at the inner canthus. Thus the veins of the eyelid, and through them those of the face, communicate with the cavernous sinus through the ophthalmic vein, so that an infection of the eyelid or face is capable of causing septic thrombosis of the cavernous sinus.

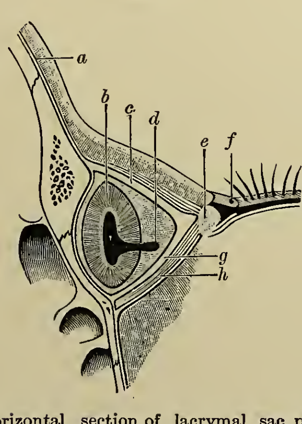
The **free border** of the eyelids, averaging 3 cm. ($1\frac{1}{5}$ in.) in *length*, consists of a *ciliary portion* (outer five-sixths) and a *lacrymal portion* (inner one-sixth) separated by the projecting *papilla* on which is the *punctum*. The *ciliary portion* is flattened and 2 mm. thick. The two or three rows of obliquely implanted *hairs* which it presents anteriorly may occasionally project internally and irritate the conjunctiva and cornea. This may be due to a vicious implantation (*trichiasis*) or to a general inversion of the border (entropion). Inflammation in the sebaceous glands of the hair follicles constitutes a "*stye*." The secretion of the *Meibomian glands* lubricates the cornea and renders it waterproof. When

this secretion is retained in one of the glands it gives rise to a "*tarsal tumor*" or chalazion. The border of the lid, with its sluggish terminal circulation, its junction of skin and mucous membrane, its moist surface and numerous glands, is frequently the seat of troublesome inflammation.

The Lacrymal Apparatus.—The Lacrymal Gland.—The lacrymal gland, lying within the orbit, reaches to within a few millimeters of the anterior orbital margin at its upper and outer angle, and lies between the superior and external recti. It is enclosed in a fibrous *capsule* derived from the orbital periosteum, so that, according to Tillaux, it may be opened or removed without opening the postocular space, by incising the periosteum at the margin of the orbit and stripping it off from the roof until we reach a point just above the gland. Cysts, tumors, and abscesses occasionally occur here. A lower *accessory portion* of the gland lies above the outer third of the upper conjunctival fornix, where also the *ducts* of the gland open. From this point the *tears*, neutral in reaction, fall over the front of the eyeball, flushing it of dust, etc., and are swept inward to the puncta by the contractions of the orbicularis muscle in winking.

Each *papilla* curves backward to the surface of the eye and presents at its summit the *punctum* or commencement of the *canaliculus* (Fig. 24). The position of the puncta in close apposition with the eye is well adapted for draining off the tears which collect here. Sometimes the *puncta* are *displaced* forward, so that the tears collect and overflow onto the cheek (*epiphora*). This may occur when the lower punctum only is displaced, as in swelling of the lid, entropion, or *ectropion*. Among the causes of the latter is a relaxed condition of the orbicularis, present in old age or in facial paralysis when this muscle is paralyzed, for the puncta and inner margin of the lids are held in apposition with the surface of the globe by a specialized part of the orbicularis muscle known as the *muscle of Horner* or the tensor tarsi. This muscle arises from the lacrymal bone, behind the posterior or reflected limb of the tendo oculi, and from the latter and is attached to the back of the inner end of the tarsi as far as the papillæ (Fig. 23). By drawing inward and backward the outer end of the tendo oculi, and thereby the tarsi, it may also compress the lacrymal sac. It may also help to open or keep open the canaliculi.

Fig 23



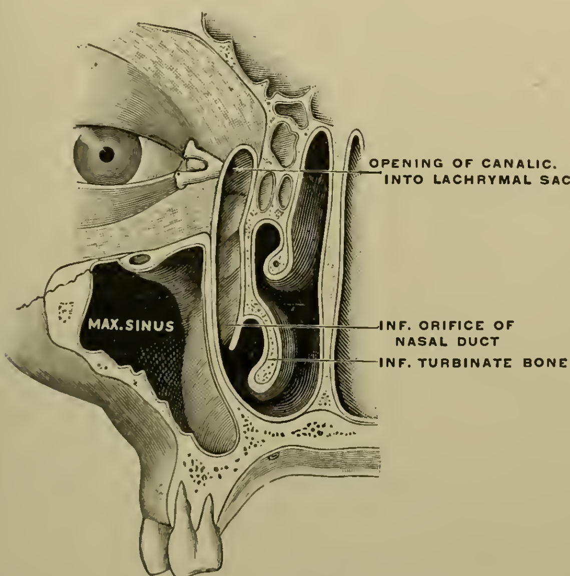
Horizontal section of lacrymal sac passing through the tendo oculi. Diagrammatic: *a*, periosteum; *b*, lacrymal sac; *c*, tendo oculi; *d*, canaliculus; *e*, caruncle; *f*, inferior punctum; *g*, tendo oculi, reflected portion; *h*, muscle of Horner. (Testut.)

The *lower punctum* is slightly external to and larger than the upper, and both are held open by a firm fibrous ring. The *canaliculi* run at

first vertically and then bend sharply and run nearly horizontally inward, a point to be remembered in passing a stylet or in injections. *Obstruction* of the puncta or canaliculi, due to the swelling or the compression of an inflammation, is another cause of the overflow of tears.

The Lacrymal Sac.—The lacrymal sac, lodged in the **lacrymal groove**, just internal to the inner canthus, receives the canaliculi antero-externally and has the following *landmarks:* The *inner ridge* bounding the *lacrymal groove* is continuous with the inferior orbital margin, and can be palpated. By drawing the eyelids externally the *tendo oculi* can be seen and felt crossing in front of the sac at the junction of its upper and middle thirds. Consequently it is below the tendo oculi and external to the above ridge that we *incise* to open the antero-external aspect

Fig. 24



Transverse oblique section through nasal canal, viewed from in front. (Testut.)

of the lacrymal sac, in case of lacrymal tumor, to give vent to pus or to introduce instruments. A *lacrymal abscess* always points below the tendon. In introducing *stylets*, etc., it is important to know the *course and direction* of the lacrymal sac and its continuation, the *nasal duct.* These together are not quite straight, but slightly curved so as to be concave posteriorly, and are directed downward, backward, and slightly outward in a line from the inner canthus to the front of the first molar tooth. Together they average a little over 26 mm. (1 in.) in length, of which the sac represents the upper two-fifths. *Lacrymal tumor* is usually due to a chronic inflammation and thickening of the lining mucous membrane. It forms a swelling at the inner corner of the orbit, and its evacuation is occasionally followed by a lacrymal fistula. *Valves* occur, but are not constant, at the opening of the canaliculi into the sac

and between the sac and the nasal duct. According to some the latter, which is the less constant valve, may be responsible for some cases of lacrymal tumor.

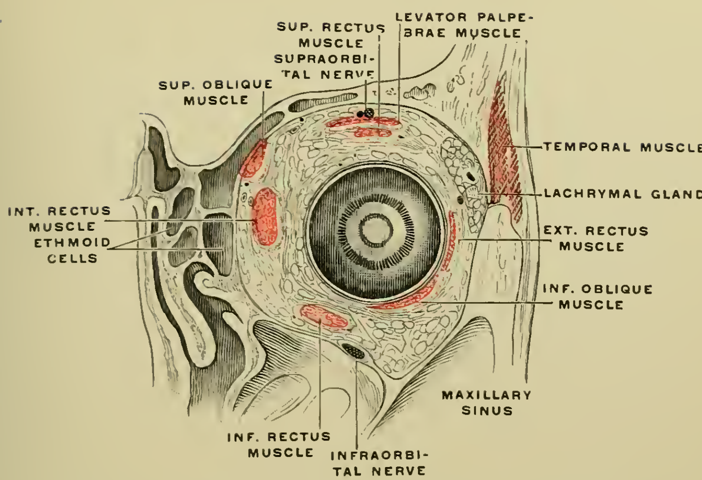
The lacrymal sac is enclosed by a **fibrous sheath** derived from the splitting of the periosteum at the ridges which bound its groove. This sheath limits the distention of the sac which may reach 6 mm. ($\frac{1}{4}$ in.) anteroposteriorly and 4 mm. transversely. The **nasal duct**, lodged in the lacrymal canal, is about 3 mm. ($\frac{1}{8}$ in.) in *diameter*, and its narrowest point is at the junction with the sac. It is the unobliterated part of the orbitonasal fissure, and opens by a vertical *slit-like opening* into the *inferior meatus* of the nose. It is difficult to find and enter this opening in the cadaver, hence catheterization from below in the living subject is too difficult to be advisable. This *lower opening* is situated about 3 cm. ($1\frac{1}{5}$ in.) behind the free margin of the ala of the nose, 8 to 10 mm. ($\frac{1}{3}$ in.) behind the anterior end of the inferior turbinate bone, in the angle between the short, oblique, anterior limb and the longer and more horizontal posterior limb of this bone, and in the angle between the lateral wall of the nose and the inferior turbinate bone.

All the ducts by which the tears are removed are *held open*, the puncta by the fibrous rings surrounding them, the canaliculi by the tensor tarsi muscle, the lacrymal sac by its fibrous sheath and the tendo oculi, the nasal duct by its bony walls. This circumstances favors the theory of Sédillot, which explains the *passage of tears* by the *vacuum* produced by the air passing across the lower opening of the duct on the principle of the mercury vacuum pump. It may also be said that the process of *winking*, due to the action of the orbicularis, keeps the puncta applied to the eye, holds open the canaliculi by means of the tensor tarsi, and compresses the sac so as to force the tears downward, as the opening into the canaliculi is guarded by a valve. After such a compression the emptied sac exerts a suction to draw the tears into it. By means of these ducts the mucous membrane of the nose and eye are continuous and inflammation may spread from one to the other. Inflammation of the sac and duct is usually an extension from an inflammation of the nasal mucosa.

The Orbit.—The anteroposterior **axis** of the pyramidal orbital cavity is directed obliquely forward and outward and measures 4.5 cm. ($1\frac{3}{4}$ in.). The **inner walls**, though convex laterally, are nearly parallel with one another, a condition, like that of the parallelism of the optic axes, which is peculiar to man. The **inner wall, floor**, and **roof** are very thin. The inner wall separates the orbit from the ethmoid cells and nasal fossa, the floor from the maxillary antrum, and the roof from the cranial cavity. *Foreign bodies*, such as foils, umbrellas, canes, or sharp sticks, thrust into the orbit have readily *penetrated* through these thin walls into the ethmoidal cells, the nose, the antrum, or the cranial cavity. These walls offer little resistance to *tumors* extending into the orbit from the surrounding cavities, or vice versa. This is especially seen in tumors of the antrum which elevate the floor of the orbit, destroy the intervening bone, and displace forward the orbital contents, causing exophthalmos.

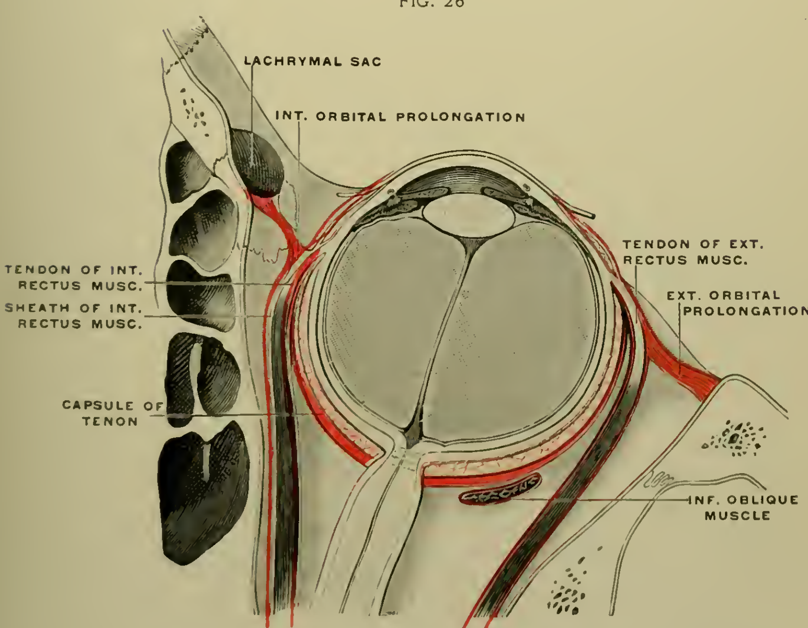
PLATE II

FIG. 25



Frontal Section of the Left Eye. (Merkel.)

FIG. 26



Partly Diagrammatic Horizontal Section of the Right Orbit and Eye, to show the arrangement of the capsule of Tenon. Lower segment of the section. (Testut.)

The presence of the bony *groove* and *canal* for the *infra-orbital nerve* in the floor of the orbit should be borne in mind, for the nerve is liable to be pressed upon by tumors of the orbit or antrum. There are various channels of *communication* between the orbit and the *surrounding cavities.* It communicates with the *cranial* cavity through the optic foramen and the sphenoidal fissure at the apex of the orbit, with the *nose* through the nasal duct, and with the *zygomatic* and *sphenomaxillary fossæ* through the sphenomaxillary fissure. Through this fissure blood may find its way into the orbit after violent blows on the temporal region.

At each angle between the orbital walls there is some point of interest. Thus, at the *supero-internal angle* are the *ethmoidal canals* (and the pulley for the superior oblique); at the *infero-internal angle,* the *lacrymal canal;* at the *infero-external angle* the *sphenomaxillary* fissure; and at the *supero-external,* the depression for the *lacrymal gland.* The anterior end of the *sphenomaxillary fissure,* through which we pass the flexible saw in removal of the upper jaw, is 15 mm. ($\frac{3}{5}$ in.) from the margin of the orbit. The **outer walls** are inclined to the sagittal plane at an angle of nearly 45 degrees, hence the interior of the orbit is most conveniently reached by incisions external to the globe between it and the outer wall. The bones of the orbit are especially liable to develop "*ivory*" *exostoses.* The *largest part* of the orbit is not at its margin, but about 1 cm. behind it.

The **orbital margin** is prominent and easily felt above, below, and externally, more rounded and less readily palpable internally. The eye is well protected by this prominent rim. As the *base* of the orbit is *bevelled,* so that the plane of its margin looks outward as well as forward, the range of vision is notably increased laterally, but at the same time the eye is more vulnerable from the outside. On this side the globe may be palpated as far back as its equator. Mesially the eye is protected from injury mainly by the nose. On the *supra-orbital margin* at the junction of the inner and middle thirds is the *supra-orbital notch,* or foramen, through which the supra-orbital nerve emerges from the orbit. The horizontal *diameter* of the orbital margin is about 3.7 cm. ($1\frac{1}{2}$ in.), its vertical diameter a little over 3 cm. ($1\frac{1}{4}$ in.); the similar diameters of the globe are respectively 24 and 23 mm.

The Contents of the Orbit.—About one-fifth of the space is occupied by the globe, the remainder by its vessels, nerves, and muscles, embedded in a quantity of fat (Fig. 25). In addition there is an important aponeurotic capsule, supporting the globe and limiting the action of its muscles. This is the **capsule of Tenon** or **orbital aponeurosis,** whose prolongations connect it with the muscle sheaths and the orbital periosteum (Fig. 26). The capsule of Tenon proper is that part of the fascia of the orbit which surrounds the posterior $\frac{4}{5}$, or the sclerotic portion of the globe. It extends forward as far as the cornea, joining with the conjunctiva, and is continued backward around the optic nerve, whose sheath it invests. In order, therefore, to reach the sclerotic in a tenotomy of the recti tendons for strabismus, we must cut through two layers,

the ocular conjunctiva and Tenon's capsule. This capsule separates the globe from the fat, etc., in the posterior half of the orbit; in fact, with its prolongations it forms a kind of *septum* between the globe in front and the rest of the orbital contents behind. The *inner surface* of this capsule is loosely connected with the sclerotic by lax and delicate areolar tissue and is smoothly lined by endothelium. It is, in fact, the outer wall of a large lymph space (Tenon's space), and forms a species of *socket* in which the globe moves without friction.

In order to reach their insertions in the sclerotic coat of the globe the tendons of the ocular muscles must pass through this capsule. Where they do so, opposite the equator of the globe, the aponeurosis invests the *muscle tendons* in a *fibrous sheath* which is prolonged forward to their insertions and backward toward the middle of the orbit, where it fuses with the proper sheaths of the muscles. A small serous bursa is formed on the anterior surface of each tendon. In consequence of this arrangement of the prolongations of the capsule the muscles do not retract to their limit after division of their tendons, close to their sclerotic insertion, but are held by the capsular prolongation. In this way, after tenotomy, the muscles retain a hold on the globe so that they still act on it through the capsule. Even after enucleation of the globe the muscles retain a hold on the capsule, and so may furnish some motion to the stump and the artificial eye which rests on it. This movement is more complete if the sclerotic coat is preserved. In addition, *prolongations* pass from the aponeurotic sheaths of the recti to the *walls of the orbit* a little behind their margins, where they are continuous with the orbital periosteum. Of these prolongations or bands the *external and internal,* from the sheaths of the corresponding recti to the orbital walls behind the corresponding palpebral ligaments, are the best developed. They are known as the *check ligaments,* for they check excessive outward and inward rotation of the globe. Together with that part of the capsule connecting them beneath the globe, they have been called by Lockwood the *suspensory ligament,* as they suspend the globe as in a hammock. According to Lockwood, it is important to preserve the attachments of this ligament in removing the maxilla, in order to prevent the eyeball from sinking downward. The orbital band or *prolongation* from the *superior rectus* to the orbital walls connects the latter muscle with the *levator palpebræ* just above it. Hence the contraction of these muscles is not entirely independent, and the superior rectus is to a slight extent an elevator of the upper lid, so that elevation of the eye and of the lid are very intimately associated with one another.

The *attachment* of the recti *muscles* to the *orbital walls* by means of the prolongations from their aponeurotic sheaths has the following *practical consequences.* The muscles do not retract far when divided, and they are held away from the globe by these prolongations, which act like pulleys, so that the muscles when they act do not compress the globe as they otherwise would. Furthermore, on account of the obliquely forward direction of these prolongations, the recti, when they act, do not retract the globe as much as they otherwise would, and hence do not

overpower the oblique muscles, which act weakly as protrusors. In this way the action of the recti is confined to the movements of the globe on its various axes.

The **periosteum** lining the orbit is continuous at the orbital margin with that of the surface of the face and cranium and at the sphenoidal fissure and the optic foramen with the periosteal layer of the dura.

The Muscles.—The muscles of the orbit are *inserted* into the sclerotic about $\frac{1}{4}$ inch from the cornea, or, according to Fuchs, the internal rectus 5.5 mm., the inferior 6.5 mm., the external 6.9 mm., the superior 7.7 mm. from the corneal margin. The points of insertion form a spiral which, commencing with the internal rectus and ending with the superior, gradually reaches farther from the edge of the cornea. The *tendons* of the internal and external recti are often *divided for strabismus*, and are *reached* at the above distances from the corneal margin after *incising* the conjunctiva and the capsule of Tenon. The tendons are then hooked up with a blunt hook and divided close to their sclerotic attachment. In *enucleation* of the globe this is repeated with the four recti and the oblique tendons after incising the conjunctiva and capsule of Tenon circularly a little outside of the margin of the cornea. The optic nerve is then divided by curved scissors from the outside of the globe. The latter may be enucleated without opening the posterior compartment of the orbit. The *width* of the thin flat tendons varies from 7 to 9 mm.

Muscular Actions.—The movements of the globe take place around three principal axes, which pass through its centre. The eyeball is not altered in its position in the orbit, but the cornea, or front of the eye, is moved upward or outward, etc., while the back of the globe moves in the opposite direction around the particular axes of motion, which pass through the centre of the globe. If the anteroposterior axis of the orbit were in the same line as that of the eyeball, the **superior and inferior recti** would simply elevate and depress the eye, for their line of action is in line with the axis of the orbit; but as their line of action forms an angle with the anteroposterior axis of the globe, and passes internal to its vertical axis, both muscles adduct the eye. On the other hand, both the **superior and inferior oblique** abduct the eye, and the former depresses, the latter elevates it. Hence to produce simple elevation or depression of the eye the superior oblique acts with the inferior rectus and the inferior oblique with the superior rectus to counteract the adduction of the recti muscles. Furthermore the inward rotation of the superior rectus and the outward rotation of the inferior rectus are counteracted by the opposite movements of the inferior and superior oblique muscles respectively. The **external and internal recti** produce simple abduction and adduction as their lines of action are parallel with the horizontal plane of the globe. *Abduction* is also produced by both oblique muscles acting together, and adduction by the superior and inferior recti acting together. In case of weakness, paralysis, or abnormal length of one muscle, the opposing muscle overacts and turns the eye away from the weaker side and the eye cannot be moved to the full extent if at all in the opposite direction. **Strabismus**, squint or cross-eye, is thus produced. If

the patient tries to look in the direction of the affected muscle the affected eye fails to move, so that the eyes are directed in different directions and *double vision* results. Double vision does not result on looking toward the side to which the affected eye is kept directed. To avoid double vision the patient turns his head to the side toward which the affected muscle cannot move the eye, so that the muscle is not called upon to act. Thus if the right external rectus is paralyzed, the right eye is directed internally and the patient has little difficulty in looking toward the left; but if he tries to look toward the right, the right eye fails to abduct and remains stationary. Hence the head is kept constantly turned toward the right to allow him to look in this direction, for he can move both eyes in the opposite direction.

To Detect the Muscular Paralysis by Looking at the Patient's Face.—Ranney has given the rule that "The head is so deflected that the chin is carried in a direction corresponding to the action of the affected muscles." One affected with strabismus is often able to educate himself to disregard one visual image, which would give rise to double vision, and to use the other eye as the "working eye." This is especially true in case of a double convergent squint.

The superior and inferior recti are supplied by the same nerve, the third, but the external is supplied by the sixth and the internal by the third nerve. Hence *strabismus* from weakness or paralysis of one of two opposing muscles is usually an *internal or external* one, as either the internal or external rectus is more likely to be affected without the other. There may be another reason why double *convergent strabismus* is a particularly common form. For in that congenital defect of the eye in which the rays are naturally focussed behind the retina (hypermetropia or far-sightedness) the ciliary muscle struggles to accommodate the lens so as to properly focus the rays. This action of accommodation is closely associated with that of convergence or adduction, for the third nerve supplies both muscles, so that a certain amount of the energy employed in accommodation passes into the internal recti and the child gradually acquires a convergent squint.

Nerves of the Orbit.—The fibers of the **optic nerves** decussate in the optic commissure, so that the inner half of one eye may work in harmony with the outer half of the other, for the image of an object on one side of the main axis of vision is received on the opposite (inner and outer) but corresponding side (right or left) of both eyes. When, therefore, the *optic tract* of one side is *paralyzed* by pressure, etc., the outer half of the retina on that side and the inner half of the retina on the opposite side are blind, and objects on the side opposite the lesion cannot be seen (*hemianopsia*). The optic nerve has been severed by a stab wound of the orbit and torn across or pressed upon in fractures of the orbit or of the small wing of the sphenoid. The optic nerve is accompanied through the posterior half of the orbit by an investment of dura, arachnoid, and pia, continued from the cranial cavity. These layers are not adherent together, but leave a potential space between them as in the cranial cavity. In this respect the optic differs from the other cranial

nerves from the third to the twelfth. Cases of sudden blindness without visible changes on ophthalmoscopic examination are to be explained by a hemorrhage or other effusion within this meningeal sheath.

The **third nerve** (motor oculi) *supplies* all the muscles of the orbit except the external rectus and the superior oblique, and, through the lenticular ganglion, it supplies the ciliary muscle and the sphincter fibers of the iris. Many of the *actions* of the third nerve are seen in viewing near objects. Thus both eyeballs are directed inward by the *internal recti* acting in unison, for which purpose the third nerves of the two sides are associated at their origin in the gray matter around the aqueduct of Sylvius. The *pupil* is also contracted by its sphincter fibers to cut off the peripheral rays, and the *lens* is made more convex by the ciliary muscle to focus the divergent rays.

When the *third nerve* is completely *paralyzed* the upper eyelid droops (*ptosis*) from paralysis of the levator palpebræ, there is a *divergent squint* with double vision (*diplopia*) from the unopposed action of the external recti, the *pupil is dilated* and cannot be contracted on account of paralysis of the circular fibres of the iris, and *accommodation* for near objects is *lost* from paralysis of the ciliary muscle. Movement of the globe in a direction outward and downward is still possible by means of the superior oblique and the external rectus, but otherwise the eye is motionless. The globe may *protrude* somewhat from the relaxation of three of the recti muscles. In partial paralysis these symptoms may be either partly developed or only one or two may be present. The *pupil* is *contracted* not only in viewing near objects but also under the influence of a bright light. The latter contraction is reflex, the former is a matter of accommodation. The pupil in which the reflex contraction is absent while the accommodation contraction is present, as in locomotor ataxia, is called the "*Argyll-Robertson pupil.*"

In *paralysis* of the **fourth nerve**, which *supplies* the superior oblique only, there may be little change in the mobility of the globe, for the function of this muscle may be performed vicariously, at least in part. But there will be diplopia in certain positions of the eye, for there is deviation of the eye inward on lowering the object viewed. That the muscles of the two sides may act in unison the fibers of the two nerves decussate in the gray matter around the Sylvian aqueduct.

When the **sixth nerve** is *paralyzed* there is *convergent strabismus,* with consequent *diplopia,* owing to the paralysis of the external rectus, which alone it supplies, and the unopposed action of the internal rectus. As the patient is unable to rotate the eye directly outward, the head is turned outward instead. The fibers of the two sixth nerves do not decussate at their origin, as the two external recti do not need to act in concert. The nucleus of the sixth nerve is connected with that of the third nerve of the opposite side by fibers which pass eventually into the internal rectus, so that both eyes can be directed to the right or left by the action of a single nucleus.

Paralysis of all the oculomotor nerves indicates a lesion which is probably at their central origin or at the cavernous sinus, in the wall of which they lie near together.

When the **ophthalmic division of the fifth nerve** is *paralyzed* there is anesthesia of the globe, conjunctiva, upper eyelids, and other parts supplied. Under these conditions the conjunctiva and cornea, especially the latter, are apt to be the seat of *ulceration*.[1] Hence after removal of the Gasserian ganglion for trigeminal neuralgia the eye has to be carefully protected or altogether closed.

The **supra-orbital branch** of this nerve, which supplies the scalp nearly as far back as the lambdoid suture, is not infrequently the seat of neuralgia. When it demands operative treatment it may be readily exposed by a horizontal *incision* centring at the junction of the middle and inner thirds of the supra-orbital margin, where the notch if present can be felt. Continued pressure on the nerve at this point may be used to detect a person shamming insensibility or to rouse a person from alcoholic coma. No malingerer can bear the pressure for long.

The effects on the eye of a *paralysis* of the **sympathetic fibers**, which reach it along the internal carotid from the cervical sympathetic, are as follows: There is some drooping of the upper lid from a paralysis of the unstriped muscle fibers (superior palpebral muscle of Müller) which extends from the under surface of the levator palpebræ muscle to the upper margin of the tarsal cartilage. There is some recession of the globe, which is explained by some as due to the paralysis of smooth muscle fibers bridging over the sphenomaxillary fissure, the *orbitalis muscle* of Müller. The *removal* of the cervical sympathetic ganglia, advised and practised for the treatment of exophthalmic goitre, may, therefore, improve the exophthalmos in this way. The *pupil* is also narrowed and loses its power of dilatation by the paralysis of the radiating dilator fibers of the iris. Of these several symptoms only the ptosis is permanent. The caliber of the blood vessels of the orbit has not been observed to change in paralysis of the cervical sympathetic.

Damage to the orbital nerves may be due to fractures of the orbit or the base of the skull, wounds of the orbit, and the pressure of tumors, aneurysms, and bloody or inflammatory effusions along their course or at their origin. The sixth nerve is more liable to be injured in fractures of the base of the skull on account of its more intimate connection with it.

Vessels of the Orbit.—The *arteries* are small and seldom give trouble when divided in enucleation of the globe, for they can be readily compressed against the bony wall. The ethmoidal arteries may be torn in a fracture of the anterior cranial fossa. *Pulsating tumors* of the orbit may be due to a traumatic aneurysm of an orbital artery, to an arteriovenous aneurysm between the internal carotid artery and the cavernous sinus, or to pressure upon the ophthalmic vein by an aneurysm of the internal carotid. In these pulsating tumors the eye is also protruded. Pressure upon the *ophthalmic vein*, or the cavernous sinus into which it

[1] This is due partly to the paralysis of the trophic nerve fibers contained in the nerve; partly to the anesthesia which allows the parts to be readily injured, as there is no sensation and the reflex winking, due to irritation of the conjunctiva, is wanting; and partly to the loss of the reflex of the sensory nerves upon the caliber of the bloodvessels, so that the progress of inflammation is unopposed.

empties, by a tumor or an inflammatory deposit, etc., causes a venous congestion of the tributaries of the vein. This congestion is visible through the ophthalmoscope as a "*choked disk.*" The presence of such a condition may assist in the diagnosis of a supposed tumor of the brain or an exudate at the base of the brain. As the facial vein, through the angular, communicates freely with the ophthalmic, and there are no valves in these veins, the venous congestion in the latter vein may be relieved through the former, if the condition has come on slowly. This same free communication renders serious any septic condition of the face in the neighborhood of the facial vein (carbuncle, erysipelas, etc.), on account of the danger of the infection extending along the veins to the cavernous sinus and setting up a septic sinus thrombosis.

The amount of **fat** (Fig. 25) behind Tenon's capsule, which embeds the other structures of the orbit, is partly responsible for the varying prominence of the eyeball in different persons or in the same person at different times. The absorption of this fat in cases of wasting disease or prolonged illness causes the sunken eye characteristic of such conditions. This loose fat allows the ready spread of **orbital abscess** which may follow injuries or inflammations of the orbit, the globe or adjacent parts. The pus may occupy the entire posterior compartment of the orbit (*i. e.*, behind the capsule of Tenon) and displace the eyeball forward, limiting its movements. The pressure on the vessels interferes with the venous circulation and causes great redness of the conjunctiva and swelling of the lids. A similar effect may be produced by *emphysema* of this fatty tissue, which may result from fracture of the inner wall of the orbit involving the nasal fossa and which is increased on blowing the nose. This fat also furnishes a favorable site for the growth of *tumors* and the lodgement of **foreign bodies**. Some of the latter are of remarkable size and shape, and they have sometimes remained for long periods of time without causing much trouble. For example, a case is described by Lawson where an iron hat peg three inches long lodged in the orbit for several days without the patient knowing it. In other cases suppuration takes place and nature gets rid of the foreign body through the opening or incision of the abscess. In a remarkable case of this kind, described by Furneaux Jordan, a man, several weeks after threshing wheat, ejected from a bed of pus, by pressure on the lower lid, a sprouting grain of wheat which had set up a severe ophthalmia.

THE NOSE, NASAL FOSSÆ AND ACCESSORY SINUSES.

The External Nose.—The external nose is largely for cosmetic purposes, a fact strikingly illustrated by the hideous appearance of those with marked nasal deformity. The *nasal cavities* serve the *functions* of olfaction and respiration (filtering, warming and moistening the air), and assist in the taste and voice.

The *groove* between the nose and the cheek is a favorable site for *incisions*, as in excision of the maxilla, for the resulting scar is scarcely

perceptible. From without inward we find the following *layers* composing the nose.

1. **The Skin.**—The skin is thin and loosely adherent over the bony portion of the nose, thick and closely adherent in the cartilaginous part. Hence in plastic operations the skin readily lends itself to the formation of flaps in the former situation, but not in the latter. The skin is very *vascular*, so that wounds and plastic operations heal well. This vascularity explains the readiness of the nose to assume a rosy color from the dilating effect on the vessels of heat, cold, alcohol, etc. In alcoholics, in those exposed to the weather, and in some chronic dyspeptics the superficial vessels become permanently dilated. The skin of the lower part of the nose is furthermore very richly supplied with *sudoriferous* and *sebaceous glands*, so that it is a favorite site for acne. The hypertrophic form of acne, known in this situation as "grog blossom," may produce a red tuberous enlargement of considerable size. From an experience of several cases I have found that this disfigurement may be satisfactorily treated by shaving down and shaping the nose, taking care not to cut through the mucous membrane, and then skin grafting the surface or allowing it to cicatrize. *Lupus*, lupus erythematosus, and *epithelioma*, or rodent ulcer, are frequently met with here, the latter especially in the alar sulcus. Plastic operations for epithelioma, or removal followed by skin grafting, give excellent results. Notwithstanding the abundant blood supply, the nose, like the ear, is prone to *frostbite* on account of its exposed situation and the superficial position of the vessels, the circulation of which at the edge of the nostril is terminal. The vascularity of the lower part of the nose favors congestion, which partly accounts for the pain in inflammation here; for, owing to the density of the closely united skin and subcutaneous tissue, the swelling due to congestion necessitates pressure upon the nerves. These *nerves* are branches of the first or second divisions of the fifth nerve.

The next layer, (2) the **subcutaneous tissue**, has already been referred to. It is loose above, dense below. The subjacent or *fibromuscular layer* (3) requires no special notice. (4) The **osteocartilaginous layer** forms the framework of the nose. This is also supported by the osteocartilaginous *nasal septum*, the loss of substance of which, especially in its cartilaginous portion, may affect the shape of the nose.

The movability of the lower or cartilaginous part of the nose obviates many **fractures**. The latter are most common through the lower most prominent and thinnest third of the nasal bones. In the upper third fracture is most rare on account of the thickness and firm support of the bones, but it is here most serious, for it requires considerable force, which is liable to be communicated to the vertical and cribriform plates of the ethmoid and thus cause an indirect fracture of the base of the skull. The *displacement* of bony fragments in a fracture of the nose is due solely to the direction of the force, and should be *reduced* by elevation from within the nasal cavity, as by the beak of a small steel sound, combined with manipulation from without. Otherwise *deformity* results. *Union* of the fragments has been observed as early as the seventh day

(Hamilton), and it occurs more rapidly than with any other fracture. As (5) the **mucosa** is intimately adherent to the bone, it is almost always torn through in a fracture rendering the latter compound, so that *epistaxis* is the rule, and subcutaneous emphysema is likely to occur and to be increased on blowing the nose. We not infrequently see marked *depression* of the bony portion or bridge of the nose, "saddle nose." This depends not so often upon a fracture as upon imperfect development from malnutrition in those with inherited syphilis. The cartilaginous part may also be destroyed by the ulceration of lupus, syphilis, or epithelioma.

The various deformities of the nose, on account of the hideous disfigurement often produced, have led to numerous **plastic operations** (*rhinoplasty*). Some of these were practised centuries ago. *Partial rhinoplasty* often gives excellent results. A *depressed bridge* of the nose may be improved by the introduction beneath the skin of an aseptic substance to fill out the depression. The difficulty in *total rhinoplasty* is that a nose made of soft parts has no firm support and is liable to contraction. For this reason the *Indian method,* by which the new nose is made of a flap from the forehead, the pedicle of which receives the frontal branch of the ophthalmic artery, has been modified to include in the flap the outer table of bone, and the flap is not twisted as in the Indian method, but inverted, and its raw outer surface covered by skin flaps from the sides. In cases where there is an actual loss of the nose and not a mere deformity the operation is advisable.

The limits of the *cartilaginous part* should be remembered, for in introducing and opening a nasal speculum the latter should not be passed beyond those limits, otherwise pain results. The lower of the two pairs of **cartilages** of the nose are curved around in front of the nostril, whose contour they form. The mesial interval between their internal branches can be felt at the tip of the nose, and into it projects the septal cartilage. The latter can, therefore, be reached and resected by a median incision between the lateral cartilages without opening the nasal cavities.

Several **operations** are performed on the nose to *expose the nasal fossæ* or even the *nasopharynx* behind. In *Rouge's operation* the incision is made through the mucous membrane, where it is reflected from the gums to the upper lip, between the second bicuspids of both sides. Then the soft parts which connect the upper lip and nose to the bone are divided and the lip turned well up, exposing the anterior part of the nasal fossæ. These may be more fully exposed by turning up the movable portion of the nose by separating the alar cartilage from the bone and dividing the septal cartilage. No visible scar is left. Or the nose may be turned down after incising the soft parts in the groove on either side of it and across its root and dividing the bone in the same line.

The *suture* between the nasal and frontal bones at the root of the nose is a favorite place for *meningoceles,* etc. They have been mistaken for nevi, being often covered by a thin vascular skin. In rare instances they escape through the cribriform plate into the nasal fossæ, and being

mistaken and treated for a polypus, the cribriform plate has been injured and fatal meningitis resulted.

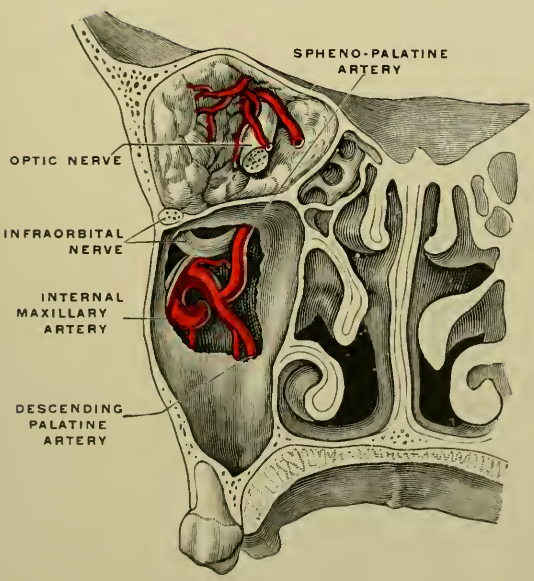
The nasal fossæ open in front by the nostrils and communicate behind with the nasopharynx through the posterior nares. The **nostrils** or **anterior nares** look downward and are at a somewhat lower level than the floor of the nasal fossæ. Hence in *examining* the fossæ through a speculum the tip of the nose is raised and the head is thrown back. In this manner the floor of the nose, the lower part of the septum, the greater part of the inferior turbinate bone, and the lower margin of the middle turbinate may be seen, with a good light. The nostrils are separated by the *columna,* composed of skin and fibrous tissue, which extends below the septal cartilage, and the latter may be reached by splitting the columna mesially.

The **anterior nasal orifice** is the heart-shaped anterior or facial aperture of the bony nasal fossæ, *measuring* 3 cm. ($1\frac{1}{4}$ in.) vertically and a little less transversely in its widest part. It can be palpated by the finger introduced through the nostril. The portion of each nasal fossa between the anterior nasal orifice and the nostrils is called the **vestibule**, and differs from the rest of the fossa in being covered by the cartilaginous part of the nose and in being lined by a squamous epithelium, a continuation of the skin. This is beset near the nostrils with stiff *hairs* (vibrissæ) which serve to *filter* the air and arrest particles of dsut. It is also provided with sebaceous glands and is liable to eczema and to painful furuncles originating in the glands, etc.

The **posterior nares** are symmetrically placed on either side of the posterior border of the nasal septum, which forms their mesial boundary. They *measure* 2.5 to 3 cm. (1 to $1\frac{1}{4}$ in.) vertically and 12 mm. ($\frac{1}{2}$ in.) transversely in the skeleton, but these measurements are reduced somewhat by the covering of mucosa and, in the upper and outer aspects, by the projection of the Eustachian tube. They may be seen with difficulty by *posterior rhinoscopy,* in which a small mirror is introduced behind the soft palate. Through this can be seen, under favorable circumstances, the posterior part of the septum, and of the turbinate bones and meati (especially the middle and inferior), also the openings of the Eustachian tubes and the roof of the pharynx. The same parts may be felt by the finger introduced through the mouth and above the soft palate. The *posterior nares* are sometimes **plugged** to arrest bleeding from the nose. For this purpose a pyramidal plug of several folds of gauze is made whose base measures a little more than the posterior nares. This is threaded with two ligatures from the apex and one from the base and pulled up into place from behind by means of a cord which has been passed through the inferior meatus into the pharynx and out through the mouth by a Bellocq's sound or a soft catheter. The two cords pass out through the nostril and are there tied tightly over a plug in the nostril, thereby plugging the latter and holding the posterior plug snugly in place. The single cord from the base of the plug is passed out through the mouth to be used in withdrawing the plug. The same object may usually be more easily accomplished by inserting a strip of gauze through the nostril and packing it well into the nasal fossæ.

PLATE III

FIG. 27



Transverse Vertical Section of the Nasal Fossæ. (Zuckerkandl.)

Viewed from in front, showing the back of the right orbit and the right antrum of Highmore, with the sphenomaxillary fossa behind the latter, exposed through an opening of its posterior wall.

The Nasal Fossæ (Fig. 27).—The nasal fossæ *lie* beneath the cranium, above the mouth, and between the orbits and maxillary sinuses. They are very *narrow* above, but widen out somewhat below, so that while there intervenes a space of 4 to 5 mm. between the inferior turbinate bone and the septum, only 2 mm. intervenes between the latter and the superior turbinate bone. In fact, the latter space is so narrow that surgically the superior turbinate bone practically forms the roof of the nasal fossæ. Owing to the narrowness of the fossæ, polypus or other *forceps* are best introduced so as to be opened vertically.

The **floor** is the widest part of the nasal fossæ, and measures at its centre, or widest part, 12 to 15 mm. ($\frac{1}{2}$ to $\frac{3}{5}$ in.) in width. It is smooth, concave transversely, and slanted slightly downward behind, so that in the erect position secretions drain backward to the pharynx.

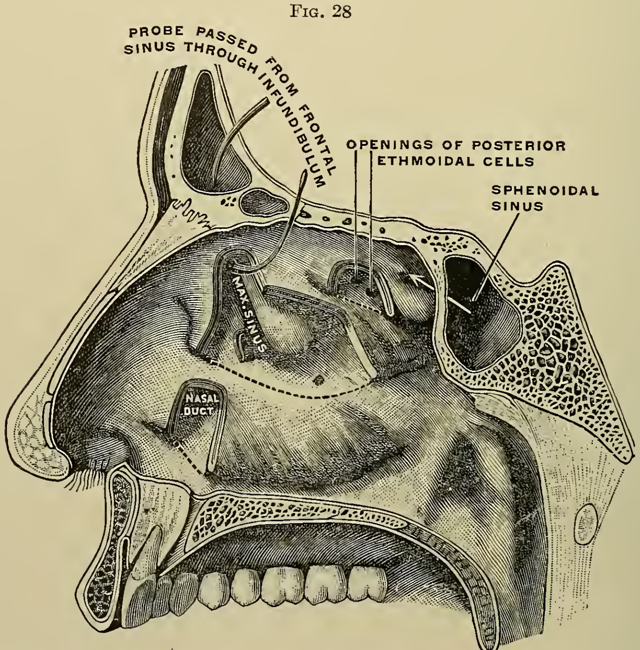
The roof is extremely *narrow*, 2 to 3 mm. ($\frac{1}{12}$ to $\frac{1}{8}$ in.), so that surgical exploration or operation here is nearly out of the question, and there is little danger of its penetration by anything as large as a polypus forceps. Yet it has been *perforated* by slender bodies, by accident or design, and the cranial cavity thereby opened through the cribriform plate. In such cases, or in fracture of this plate involving the mucosa beneath it, there is bleeding from the nose, the discharge of cerebrospinal fluid, if the subarachnoid space is opened, and the danger of meningitis, as it is impossible to make and keep the nose aseptic. In fact, meningitis has resulted from the extension of inflammation through an intact nasal roof in case of inflammation of the nose. *In front* of the cribriform plate the roof slants downward. It is here formed by the nasal bones and the nasal spine of the frontal, and above the latter lie the frontal sinuses. *Behind* the cribriform plate the roof slants more abruptly downward, and is formed by the anterior surface of the sphenoid containing the openings of the sphenoidal sinuses. It follows that the *height* of the fossæ is greatest about their centres.

The median wall or septum is straight in children up to the seventh year and in aborigenes; but in adults it *deviates* to one side in over 75 per cent., usually to the left, but according to many to the right. A deviation may follow an injury, but this is not the common cause. It probably depends upon the faulty development of the superior dental arch, especially its premaxillary portion, so that the septum grows more rapidly than the space for it enlarges. It is attributed to the continued growth of the septal bones in the vertical plane after they have united at their edges. The nose, as a whole, is seldom absolutely straight, and this has been attributed to blowing the nose with the same hand, usually the right, sleeping largely on the right side, etc. The septal deviation may involve the bony (53 per cent., Zuckerkandl) or the cartilaginous portions alone, or both. It most often occurs at the junction of the ethmoid and vomer, or at that of the latter with the septal cartilage, and if it is marked it may more or less block one nasal fossa by contact with the turbinate bones. This *contact* is a source of constant irritation, and may result in fusion of the parts (synechia). Until we examine the opposite fossa and note the concavity of the septum we may mis-

take the deviation of the septum for a septal tumor, abscess, or hematocele, or even a nasal polyp. There are many *operations* for the restoration of the blocked fossa or the straightening of the septum. Exostoses or "*spurs*" are liable to grow on the septum, especially at the junction of the bony and cartilaginous portions. As the septal cartilage is the principal support of the cartilaginous part of the nose, its destruction by syphilis causes great flattening of it. Syphilitic destruction of the bony and cartilaginous septa and of the adjacent bones may result in the flattening of the bony vault also.

The **mucosa** covering the *septum* is blended with its periosteal and perichondral covering into a single dense layer, and the layer thus formed is loosely attached to and easily separated from the septum. Hence

Fig. 28



External wall of right nasal fossa, parts of the turbinates having been cut away to show the orifices of the sinuses which open into the meatuses. (Gerrish, after Testut.)

collections of blood or pus may readily form beneath the mucoperiosteal covering; also by stripping up the latter the septum may be exposed and operated upon without entering the nasal cavity.

The Outer Wall (Fig. 28).—The outer wall has a general slant from above downward and outward. The anterior end of the **inferior turbinate bone** reaches to the anterior limit of the bony outer wall and within about 2 cm. ($\frac{4}{5}$ in.) of the nostril. The posterior end of this bone is at the posterior nares, on a level with the opening of the Eustachian tube. The free border of the inferior turbinate bone may extend so far toward the floor of the nasal fossa as to interfere with the introduction of instruments along the **inferior meatus**. The latter is the *widest* part of the nasal

fossæ, measuring about 12 mm. ($\frac{1}{2}$ in.). Its greatest *height* 18 mm. ($\frac{3}{4}$ in.) corresponds to the opening of the *nasal duct*, which is about 2.5 to 3 cm. (1 to $1\frac{1}{5}$ in.) behind the nostril (see page 72). The sharp downward slant of the anterior fourth of the inferior turbinate bone renders the *height* of the inferior meatus but little in front and less here than it is behind. Hence *inspired air* is not so apt to enter this meatus, *expired air* more apt to. This tendency is increased by the downward direction of the nostrils, the consequent upward current of inspired air, the wide funnel-shaped anterior end of the middle meatus (*the atrium*), and the narrowed posterior end of this meatus. This explains the fact that we *smell inspired air*, for it passes through a meatus (middle), part of whose walls is supplied by the olfactory nerves, as well as the fact that we do not smell expired air, for it passes largely through the inferior meatus, which the olfactory nerves do not reach. Also, if we wish to *smell* an object we dilate the nostrils and sniff up the air, which thereby is carried into the upper or olfactory part of the fossæ. On the other hand, discharge in the middle meatus or upper part of the vestibule cannot be so readily removed by blowing the nose, for the expired air passes below it.

The anterior end of the **middle turbinate bone** inclines upward so that it reaches the *level* of the inner canthus of the eye. This upward inclination makes the **middle meatus** open up widely in front into the *atrium*, into which an instrument, introduced through the nostril, passes more readily than into the inferior meatus, unless care is taken. About the centre of the middle meatus is the slit-like *opening of the antrum*, about 2.5 cm. (1 in.) above the floor of the nasal fossa and nearer the roof than the floor of the antrum. This opening is at the lower end of a deep groove, the *infundibulum*, which curves downward and backward, overhung by the anterior half of the middle turbinate. In about half the cases its upper end receives the canal leading from the *frontal sinus* (*ostium frontale*); in the other half of the cases the infundibulum ends blindly. Into this groove open also the anterior *ethmoid cells*.

The Mucous Membrane.—The mucous membrane varies in different parts of the nasal fossæ. Behind the vestibule each nasal fossa is divided into an upper *olfactory region*, including the middle and upper turbinate bones and the upper third of the septum, which is covered by columnar epithelium, and a lower **respiratory region**, including the rest of the fossa, which is covered by columnar, ciliated epithelium. On the outer wall between the turbinate bones and on the floor the mucosa is thin, elsewhere it is thick and vascular, especially over the turbinate bones. This *thickness* over the turbinates is largely due to the abundant submucous *venous plexus*, the meshes of which run mostly anteroposteriorly. The mucous membrane extends in a fold beyond the inferior turbinate bone in front, behind, and below. Over this bone the veins of the thick mucosa form a kind of cavernous or *erectile tissue*. This may swell up rapidly from engorgement of the veins so as to come in contact with the septum, and this contact is in itself a source of irritation. The rapid shrinkage of this "erectile body" when a caustic or astringent is applied to it is very striking.

The *acinous glands* of the mucosa, secreting for the most part a thin watery fluid, are most numerous over the inferior turbinate bone and the middle and posterior parts of the fossæ. They account for the profuse secretion in coryza. The normal *function* of this *secretion* appears to be to moisten the inspired air and to aid the cilia in the removal of the dust and microörganisms filtered from the air. The chief function of the great *vascularity* of the mucosa is to warm the inspired air. *Adenoid tissue* is abundant in the mucosa of the posterior part, and is continuous with that of the nasopharynx. Several of the *openings* found in the bony fossæ are closed by the mucosa, and others may be temporarily closed by the swelling of this membrane. From the relations of the nasal fossæ and the continuity of its mucosa with that of other parts it follows that *inflammation* of this mucosa (coryza) may *spread through* the posterior nares to the pharynx and to the Eustachian tubes, through the nasal duct to the lacrymal sac and conjunctiva and through the infundibulum to the frontal and maxillary sinuses and the ethmoid cells. One or more of these extensions is often exemplified in a coryza.

Swollen turbinate bones may be mistaken for **mucous polypi** which are common in the nose and usually arise from the inferior or middle turbinate bones. They often grow in crops, block the fossæ, and may press upon and widen the nose or obstruct the openings on its outer wall They may be *removed* with the snare or polypus forceps, care being taken not to damage the cribriform plate in case of high attachment. The fibrous and sarcomatous polypi take origin, as a rule, from the periosteum of the roof of the nose or pharynx and spread in all directions.

The Blood Supply.—The blood supply of the nose is derived from three sources, the ophthalmic, facial, and internal maxillary. The *veins,* in addition to accompanying the arteries, communicate with the superior longitudinal sinus through the foramen cæcum in children and sometimes in adults. This communication and that with the cavernous sinus through the ophthalmic veins help to explain intracranial complications in some cases of inflammation of the nasal cavities.

Bleeding from the nose, or *epistaxis,* may be due to fracture or other injury, general oozing of the vascular mucosa, ulceration or venous congestion, as in cardiac or pulmonary disease, or cerebral congestion. When due to congestion the patient should be kept erect to aid venous return, and the raising of the arms is recommended on account of the resulting expansion of the thorax and its aspiration upon the cervical veins. In some cases the bleeding is vicarious. The *ulcerations* are apt to be on the *septum,* where they should be sought for. Nose bleed may be *profuse* and *long continued;* as much as 75 pounds of blood has been lost altogether (Fränkel), and it has continued for twenty months on and off (Spencer Watson). If it resists local applications, *plugging* of the nares or nasal fossæ (p. 82) may have to be employed to arrest a fatal result, which has occasionally occurred. The great vascularity of the nasal mucosa accounts for the frequent occurrence of epistaxis.

The Lymphatics.—The lymphatics communicate through the cribriform plate with the subdural space, and also enter the upper nodes of the

internal jugular chain (deep cervical), the submaxillary and retropharyngeal nodes. Abscess of the last-named nodes may, therefore, be due to disease of the nose, and in lymphadenitis of the cervical nodes we are forced by exclusion in many cases to assume, if we cannot prove, that the source of infection was in the nose or nasopharynx.

The Nerve Supply.—The nerve supply, apart from the olfactory nerve, whose distribution has been given above, is from the first and second divisions of the *fifth nerve.* The *nasal branch* of the *ophthalmic division* of the fifth nerve supplies the anterosuperior part of the nasal fossæ and explains the following *reflexes* in connection with other branches of this division of the nerve—*i. e.,* the *lacrymation* that may follow a pungent odor and the *sneezing* from looking at bright sunlight. In the former case the irritation is referred to the lacrymal branch of the same division, and in the latter case it is probably referred from the nerves of the orbit to the nasal branch. *Sneezing* also follows the direct irritation of the nerves of the nose by chemical or mechanical irritants like snuff or dust or the abnormal contact of the septum and outer wall of the nose. In the above instances sneezing probably depends upon the relation between the trigeminus and vagus nerves. Curious accidents have occurred during violent acts of sneezing. Thus, Treves mentions fracture of the ninth rib, dislocation of the shoulder, and rupture of all the coverings of a large femoral hernia.

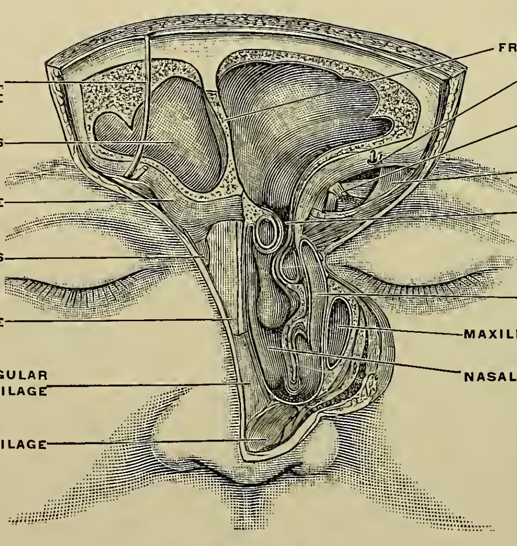
The lodgement of **foreign bodies** in the nose is quite common. That they may remain in some cases for long periods of time without causing much trouble is illustrated by a case reported by Tillaux of an old woman from whose nose he removed a cherry stone that had lodged there for twenty years. When they remain long they may become encrusted by calcareous matter and thus form rhinoliths which are most common in the lower meatus. In some cases of chronic purulent discharge from one nostril the cause may be the presence of a bean, bead, button, or other foreign body in the nose.

The **nasal douche** may be used in more than one way. Thus, with the head lowered a little and the mouth open, the nozzle of the irrigator is introduced into one nostril and the fluid flows out of the other after passing from one fossa to the other behind the posterior nares. This is possible from the fact that in breathing through the mouth the palate is elevated, so as to be in line with the nasal floor behind the posterior nares, and shuts off the nasal fossa from the pharynx. But at the same time the Eustachian tube is opened by the same mechanism that raises the palate, and there is some danger of infection being carried into it. Again, with the head tilted slightly backward, the douche may be allowed to flow back until it reaches the pharynx, the mouth being kept closed.

The Accessory Sinuses of the Nose.—**The Frontal Sinuses.**—The frontal sinuses do not exist at birth, but their evolution occurs between the seventh and twenty-first years. They may be considered as *developed* from the diploë and hence lie between the inner and outer tables of the skull, or they may be considered as prolongations of the ethmoid cells. They are *situated* above and external to the nose, above and internal to the

orbits, and beneath and in front of the cranial cavity. They lie on either side of the glabella and behind the *superciliary ridges,* whose prominence they form. But the absence of these prominences does not necessarily imply absence of the sinuses, as they may extend backward only. The orbital and cranial walls of the sinuses are formed by thin bony lamellæ; the anterior wall contains a small amount of diploë. The sinuses are divided into two lateral halves by a *septum,* often thin but rarely incomplete, except from disease. The septum is median inferiorly, but deviates to one side above. Sometimes the sinuses are so small as to be scarcely noticeable; at other times they may be large enough to contain two or more ounces, or to contain a foreign body of some size. In *old people* these sinuses may enlarge as the brain shrinks. Well-developed sinuses may extend 5 cm. (2 in.) upward, 3.5 cm. ($1\frac{1}{2}$ in.) outward, and nearly as

Fig. 29



Frontal sinus. (Bardeleben.)

far backward, but the average size is nearly one-third less. In *injury* to this region there may be a *depressed fracture* without damage to the cranial cavity. In this case *air* may be forced through the opening on blowing the nose and cause frothing of the blood if the fracture be compound, or subcutaneous emphysema or emphysema of the orbit in a simple fracture. In the adult, therefore, fracture here is less serious than elsewhere in the skull, as the brain-case may be spared.

Each frontal sinus is lined by a pale, thin, loosely adherent *mucosa* continuous with that of the middle meatus of the nose, through the infundibulum in about half the cases, and through a separate passage or through both in the remaining 50 per cent of cases. Hence they are liable to an extension of *inflammation* from the nose, which accounts for the frontal *headache* in some cases of coryza, ozena, etc. The passage

to the nose is deeply placed near the inner wall of the orbit and its opening into the infundibulum is about on a line with the tendo oculi. By the swelling of the mucosa of the infundibulum its lumen is temporarily occluded. The upper opening of the duct is on the inner and back part of the floor of the sinus, above and behind the internal angular process. The duct is directed downward with a slightly backward curve, through the anterior ethmoidal cells, and is well placed for drainage. But when it becomes occluded by inflammatory swelling and pus forms, we have **empyema** of the frontal sinus or sinuses. Eventually, in such cases, if drainage is not provided, the walls give way at their weakest point, which in 90 per cent. of cases is in the orbital roof, and the abscess finally discharges through the inner half of the upper lid. Occasionally the posterior wall of the sinus is eroded and perforated, giving rise to a subdural abscess or pachymeningitis, or in some cases meningitis or brain abscess. The anterior ethmoidal cells are not infrequently involved, together with the sinus. A frequently valuable sign of this complication is pain localized at the inner canthus of the eye.

The frontal sinuses require *opening* by the chisel, burr, or trephine in cases of empyema, and are generally reached by a horizontal *incision* just above the inner half of the supra-orbital margin, through the eyebrow. The reëstablishment of drainage into the nose is most important.

In some curious cases insects like centipedes, larvæ, and even maggots have found their way into the frontal sinuses, in the latter case setting up a violent septic inflammation. Bony tumors may grow from the fibrous layer lining the deep surface of the mucosa.

The Antrum of Highmore or Maxillary Sinus (Figs. 24 and 27).—The antrum of Highmore or maxillary sinus is present at birth, but continues to grow until old age, when its walls become very thin. It occupies the body of the maxilla and is pyramidal in *shape*, with its base internally toward the nasal fossa. Its anterior or **facial wall** is the thickest, but the most accessible, so that the *opening of an empyema* of the antrum is often made on this surface above the first or second molars, after incision of the mucous membrane, where it is reflected from the gums to the cheek. Inflammation and *empyema* of the antrum may be due to the diseased root of a tooth, especially that of the first and second molars. The *roots* of the latter *teeth* often cause a *prominence* in the lower part of the antrum, and may even project uncovered into it. In diseased conditions the sockets of almost any of the teeth may communicate with it. When the diseased root of a first or second molar is drawn it may open and drain the antrum from its lowest point, but this method of drainage as an operation of choice has the disadvantage that it allows food particles to enter the antrum. Behind the antrum is the **sphenomaxillary fossa** (Fig. 27) containing **Meckel's ganglion,** to remove which the route through the antrum, after resecting its facial and zygomatic walls, has been employed (Carnochan's method). The **upper wall** separating it from the orbit is very thin, so that tumors of either of these cavities readily extend into the other. As this wall contains the *infra-orbital nerve,* in a groove and canal, and the anterior and posterior walls contain the nerves of the upper

teeth, tumors, retained pus, etc., which press upon these walls, are likely to cause neuralgia of the face and teeth. The **inner wall** or base corresponds to the outer wall of the nose in the inferior and middle meati, in the latter of which at the lower end of the infundibulum is the *orifice* of the antrum. As this is above the middle of the cavity it is not well situated for drainage. Sometimes, in about 10 per cent. of cases, there is another opening, a little farther back, which is pathological in many cases. This wall is so thin as to be readily perforated. Advantage is taken of this by perforating through the inferior meatus for drainage in the treatment of empyema of the antrum. The **mucosa** of the nasal fossa is continuous with that of the antrum, and in this way inflammation may extend from the nose to the antrum. The mucosa of the antrum resembles that of the frontal sinus, but is somewhat more vascular and more richly supplied with mucous glands. The latter are quite prone to cystic formation, whereby the antrum may be partly or wholly filled, a condition sometimes erroneously called dropsy of the antrum.

Tumors of the upper jaw may originate in the antrum or grow with great rapidity on entering it, and in either case they *distend its walls*. Thus, pushing up the roof, they invade the orbit, causing exophthalmos and diplopia, and breaking or protruding through the thin inner wall, they obstruct the nasal fossa and perhaps the nasal duct. They protrude through the bottom of the antrum onto the roof of the mouth and also form a projection on the cheek. The treatment for malignant tumors is the excision of the upper jaw; for benign tumors, their removal through an opening in the anterior wall. In case of *fracture* of the anterior wall of the antrum, *emphysema* of the cheek may be present and may be increased on blowing the nose. Occasionally the antrum is subdivided by bony septa into recesses or separate chambers.

As to **the sphenoidal sinuses** little need be said except that like the other sinuses of the face they serve the purpose of lightening the face, so that in spite of its growth the equilibrium between the anterior and posterior parts of the head at its articulation with the spine is not disturbed. Also, like the maxillary sinus, they may have some effect on the quality of the voice, acting like a sounding box. *Fracture* through them leads to bleeding from the nose, and may establish a communication between the latter and the cranial cavity. Dense *exostoses* occur within them as within the frontal sinuses, and inflammation may invade them from the nasal fossæ or posterior ethmoidal cells.

THE FACE.

This region, apart from the eyebrows, eyelids, and nose, already studied, and the parotid region and lips, to be considered later, we will study layer by layer. The *lower limit* of this region and the boundary between it and the neck is the lower border of the lower jaw.

The Skin.—The skin of the face is for the most part thin, fine, elastic, and very vascular, and thus well suited for plastic operations. Its *vas-*

cularity is seen in the ready flushing of the cheeks, in blushing and fever; in the free bleeding and rapid healing of wounds or incisions; in the varicose or injected condition of its fine vessels in those exposed to cold and in the subjects of alcoholism and acne; and in the common occurrence of nevi and various forms of vascular tumors. Keloid-like scars are comparatively common on the face, probably owing to its vascularity and frequent movement. As the skin is richly supplied with sebaceous and sweat glands, it is a favorite site for acne and *sebaceous cysts*. The latter sometimes require the use of the knife to avoid a more disfiguring scar. The skin of the face is also a favorite situation for the development of rodent ulcer (*epithelioma*) and lupus. Over the chin the skin is thick and like that of the eyebrows. When the skin over the chin or that covering the malar bone is struck by a blunt instrument or in a fall a wound may be produced simulating an incised wound, as is also the case with the scalp.

The Subcutaneous Layer.—The subcutaneous layer is in general *lax*, so that on the one hand it favors the spread of inflammation, edema, etc., and on the other hand it increases the mobility of the skin and renders it suitable for the various plastic operations done here. In *inflammation* or *edema* the face may be greatly swollen and in the latter condition the swelling first appears, as a rule, in the loose subcutaneous tissue of the lower lid. The quantity of **fat** in the subcutaneous tissue varies in different parts and under varying circumstances. Thus, it is especially abundant in the *cheeks*, or those lateral regions corresponding to the area lined by mucous membrane on the inner surface. It is firmer and more abundant in children and well-nourished persons, more scanty in old age and after wasting diseases, as indicated by hollow cheeks and prominent cheek bones. Fatty tumors are exceedingly rare here.

In this layer lie the main **bloodvessels** of the face, the principal branches of the *facial nerve* (in front of the anterior border of the masseter), a *lymph node* near the lower border of the mandible and many of the facial muscles of expression. The **facial artery**, where it crosses the lower border of the mandible, at the antero-inferior angle of the masseter, lies just anterior to its *vein*, and is covered by the skin and platysma only. Here its pulsations can be easily felt and it can be readily compressed against the bone or ligated. In passing toward the angle of the mouth and the ala of the nose, and thence up beneath the nasofacial groove, it describes the arc of a curve whose chord is formed by the straighter and more superficial **facial vein.** The free communication of the latter with the cavernous sinus, through the ophthalmic vein, explains the danger of intracranial complications like sinus-thrombosis, in case of septic processes of the face, such as carbuncle, erysipelas, malignant pustule, etc., especially when they occur near the course of the facial vein, along which the infection may spread as a phlebitis or periphlebitis.

Malignant pustule attacks the face more often than any other part (even the hands). Also in the young a form of gangrene, *cancrum oris*, sometimes attacks and extensively destroys the soft parts of the cheek to such an extent that in some cases the jaws may be firmly closed by the

contraction of the resulting scar. Owing to the free blood supply *extensive flaps* in plastic operations, or even those torn up in lacerated wounds, keep their vitality in a remarkable manner. As the *anastomosis* is very free between the two sides of the face or two adjoining branches of the artery, both ends of a divided facial artery must be sought and tied to check bleeding. The *lymph node* near the vessels as they cross the border of the mandible is often enlarged in cases of alveolar periostitis, etc., from dental caries. Abscess in this region not infrequently originates in this way.

The Nerves.—The branches of the **facial nerve** are nearly horizontal in direction. They *anastomose* and form plexuses with the infra-orbital, mental, and buccal branches of the fifth nerve. The facial nerve *supplies* the muscles of expression, hence in **facial paralysis** there is a lack of expression on the side paralyzed, the lines of the face are flattened out, and the

Fig. 30

Facial paralysis of the right side. Attempt to raise the eyebrows.

Fig. 31

Facial paralysis of the right side. Attempt to close the eyes.

surface is smoother than normal. The *cause* of the paralysis may be within the brain, in the passage of the nerve through the skull in the aqueduct of Fallopius, or external to the skull. The *symptoms* help us to determine the *position of the lesion* according as one or another branch, given off along its course, is affected or not. In a very few cases deviation of the uvula has been noted, but this is now thought to be a mere accident (Horsley and Beevor), and the levator palati and azygos uvulæ muscles, on whose paralysis it depends, are now known to be supplied by the spinal accessory, through the pharyngeal plexus, and not by branches of Meckel's ganglion derived, through the great superficial petrosal, from the geniculate ganglion. Hence the condition of the palate does not serve to locate the lesion to one or the other side of the geniculate ganglion. If the *taste* is lost on one side of the front of the tongue, the lesion is proximal to, if it is not lost it is distal to, the origin and giving off of the *chorda tympani* branch in the lower part of

the Fallopian aqueduct, for this branch conveys taste fibers from the glossopharyngeal nucleus to the tongue. Just below the aqueduct there is given off the *posterior auricular branch* which supplies the posterior belly of the occipitofrontalis and the retrahens and attollens aurem, so that these muscles are paralyzed if the lesion is proximal to this branch, but not if it is distal to it, and so on.

As the *orbicularis palpebrarum, frontalis,* and *corrugator supercilii* muscles are not involved in facial paralysis due to a lesion of the cortical facial centre of the brain, it is probable that the fibers which supply them reach the facial nerve from the *oculomotor nucleus,* or that these fibers receive a bilateral innervation. Also the involvement of the *orbicularis oris* in bulbar paralysis and the close association of the movements of the lips and tongue suggest that this muscle is supplied from the *hypoglossal nucleus* through the facial.

The *chief features* of facial paralysis are a smooth forehead and immovable eyebrow, the inability to wink or close the eye, so that the eyeball is aways exposed, the dripping of tears over the cheek (see p. 70), a flat, flabby cheek between which and the gums food lodges, the inability to whistle or pucker the mouth, and an expressionless drooping corner of the mouth, with or without partial loss of taste. *Electricity* can be applied to the nerve or its branches; to the undivided trunk by an electrode pressed as deeply as possible between the mastoid process and the cartilaginous auditory meatus. If the paralysis persists, it may be largely relieved by anastomosis of the distal end of the nerve, severed as it emerges at the stylomastoid foramen, with the spinal accessory or hypoglossal nerve.

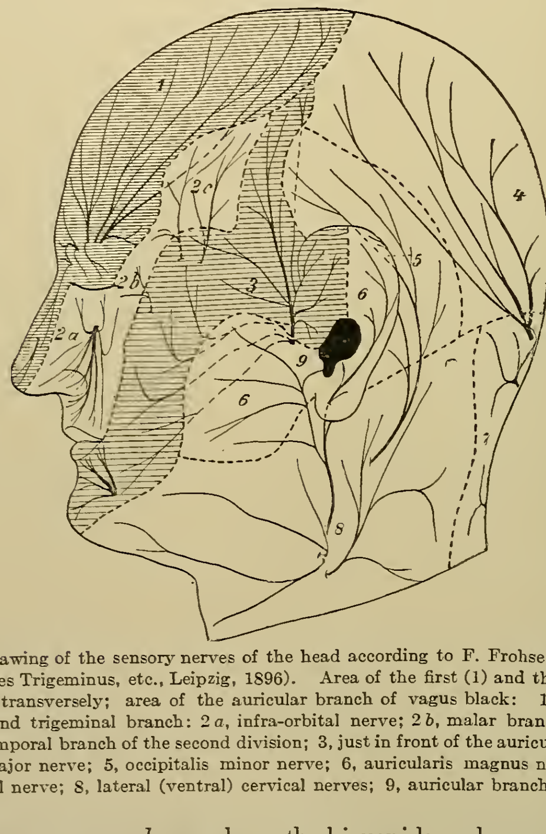
Below its exit from the stylomastoid foramen the facial nerve is *accessible* to surgical procedure through a curved or straight incision in front of the mastoid process and the sternomastoid muscle. The latter is retracted backward and the parotid gland forward, and by blunt dissection the styloid process is reached, behind which the trunk of the nerve emerges. This is short and soon enters the parotid gland, in which it branches and forms a plexus, pes anserinus. In peripheral operations for trigeminal neuralgia it is important to spare the temporal branch, which emerges from the upper end of the parotid just in front of the temporal artery, and supplies the orbicularis palpebrarum. If the operation on the Gasserian ganglion should become necessary, the functional activity of this muscle in winking is important in preserving the integrity of the eyeball.

The facial nerve is liable to be injured within the parotid or distal to it. Within the skull it is more often injured in fractures of the base of the skull than any other nerve, owing to its long course through the bony Fallopian canal.

Though the main trunks of the sensory nerves belong to the deepest layer of the face, their filaments pass through the subcutaneous layer to reach the skin. To complete the study of the nerves of the face they are best considered here. For their distribution see Fig. 32. They are branches of the *fifth nerve,* and three such branches concern the region under con-

sideration. The **infra-orbital branch** of the maxillary (second) division of the fifth nerve, after passing along a groove and then a canal in the floor of the orbit (and the roof of the antrum), emerges on the face at the *infra-orbital foramen.* This is *situated* at the upper end of the canine fossa, 8 mm. ($\frac{1}{3}$ in.) below the inferior margin of the orbit, near the junction of its middle and inner thirds and in a vertical line from the interval between the two upper bicuspids or from the second bicuspid. This, the most frequently affected nerve in trigeminal neuralgia, may be reached and injected with osmic acid or alcohol, or *resected* by

Fig. 32



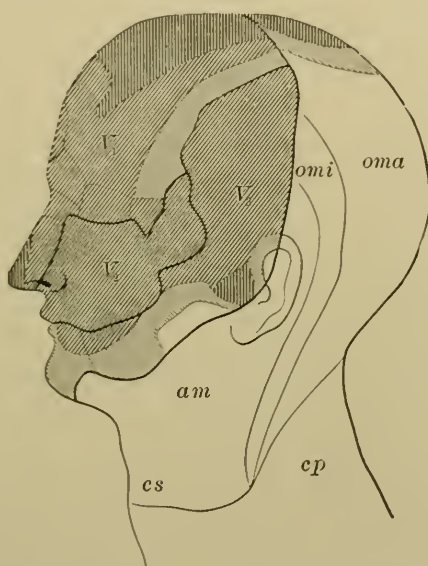
Schematic drawing of the sensory nerves of the head according to F. Frohse (from F. Krause, Die Neuralgie des Trigeminus, etc., Leipzig, 1896). Area of the first (1) and third (3) trigeminal branch shaded transversely; area of the auricular branch of vagus black: 1, first trigeminal, branch; 2, second trigeminal branch: 2 *a*, infra-orbital nerve; 2 *b*, malar branch of the second division; 2 *c*, temporal branch of the second division; 3, just in front of the auriculotemporal nerve; 4, occipitalis major nerve; 5, occipitalis minor nerve; 6, auricularis magnus nerve; 7, posterior (dorsal) cervical nerve; 8, lateral (ventral) cervical nerves; 9, auricular branch of the vagus.

incising the mucous membrane above the bicuspids and separating the soft parts from the bone, or by an oblique or angular *cutaneous incision* below the orbit. By lifting up the contents of the orbit from its floor the nerve is exposed in the bony groove in which it lies, and that part of it may be resected which lies between the groove and the foramen and the latter securely plugged to prevent regeneration of the nerve. The small arterial branch accompanying the infra-orbital nerve may usually be disregarded.

Meckel's ganglion, together with the infra-orbital branch behind the orbit, has often been **resected** for certain neuralgias of the second division

of the fifth nerve by following the infra-orbital nerve backward (Carnochan's operation). Thus, after *incising* below the orbit and then down the nasofacial groove, a flap of skin is turned back and the anterior wall of the antrum opened, up to the infra-orbital foramen. The bony canal and groove of the nerve is then laid open from beneath, and, following the nerve, the posterior wall of the antrum is trephined, opening into the

Fig. 33



Scheme showing effects of total extirpation of Gasserian ganglion forty-seven days after operation. Sensation of heat spoken of as slightly warm; sensation of cold absent: V_1 V_2 V_3, first, second, and third branches of fifth nerve; *oma*, occipitalis major; *omi*, occipitalis minor; *am*, auricularis magnus; *cs*, cervical nerves. (Freidrich.)

Zone of absolute anæsthesia and analgesia; complete loss of temperature area.

Zone of nearly complete anæsthesia and analgesia.

Zone of distinct but diminished hypalgesia and hyperæsthesia.

Area of normal sensation.

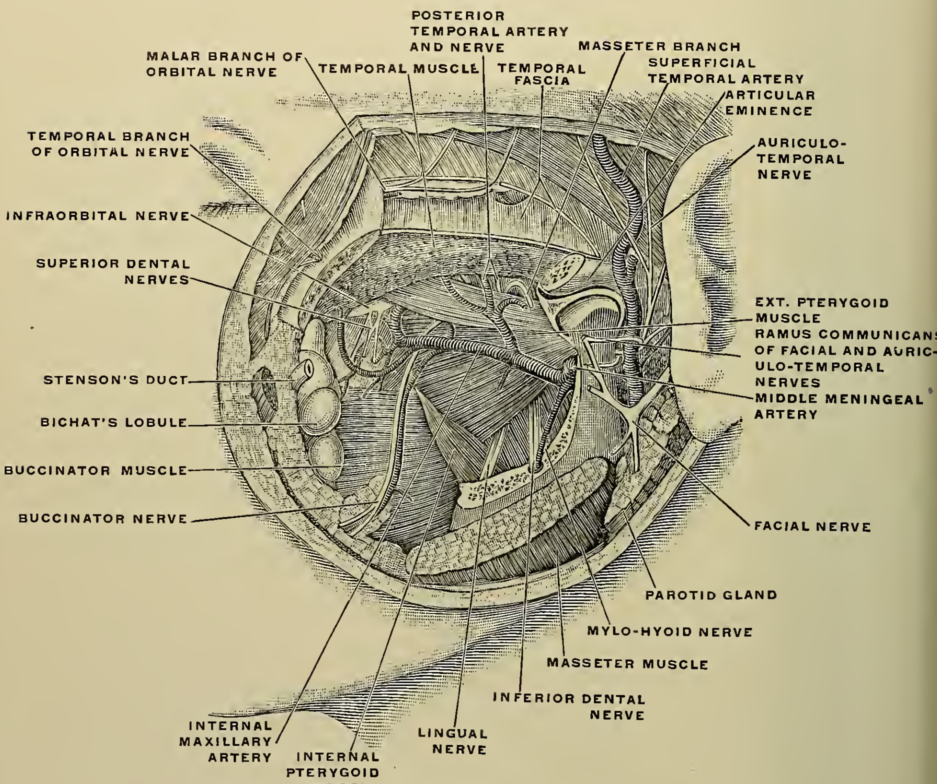
Outline of innervation zones of trigeminal.

sphenomaxillary fossa (Fig. 27). This exposes the triangular reddish ganglion 0.5 cm. ($\frac{1}{5}$ in.) in diameter, lying below the main nerve. The terminal branches of the internal maxillary artery are in close relation to the ganglion and may give rise to considerable hemorrhage, which may be stopped by pressure. External to the ganglion and nerve is the external pterygoid muscle, internal to it the vertical plate of the palate bone and the sphenopalatine foramen. Behind the ganglion the nerve trunk can

be followed back through the sphenomaxillary fossa to the foramen rotundum. Peripheral operations on the branches of the second and third divisions of the fifth nerve give only temporary relief, as a rule, in tic douloureux, but the nearer the foramina of exit the nerves are excised or avulsed the longer does this relief persist. There are many other methods of exposure of this branch.

The mental branch of the *inferior dental trunk* of the mandibular division of the fifth nerve emerges at the *mental foramen,* below the interval between the two lower bicuspids or below the second bicuspid.

Fig. 34



Lateral view of the face. Deep layer. (Bardeleben.)

It is thus seen to lie in the same vertical line with the infra-orbital foramen, and if this line is continued upward it strikes the supra-orbital notch or foramen. Hence these three branches of the three divisions of the fifth nerve emerge through bony openings in the same vertical line. In tic douloureux there are usually "tender points" where the affected branches emerge on the face, pressure at which may bring on a paroxysm. The mental foramen in the adult is midway between the lower and the alveolar borders of the jaw, in the aged near the latter, in the infant near the former. It may be *exposed* by a cutaneous *incision* or by one through the

gingivolabial fold of mucous membrane, remembering that the foramen lies 8 mm. ($\frac{1}{3}$ in.) below this fold. Its exposure is not often indicated.

The main trunk of this nerve, the **inferior dental**, may be **exposed** for exsection at its entry into the *inferior dental foramen* in one of several ways. The foramen, it should be remembered, is about *equidistant* from all four borders of the ramus; that is, about the centre of the inner surface. Surmounting the foramen in front is the *mandibular spine*, to be used as a landmark when we expose the nerve at its entrance into the foramen. This is done from *within the mouth* by *incising* the *mucous membrane* from the last upper molar to the inner side of the coronoid process, thus exposing the tendon of the temporal muscle. The finger is then introduced backward between the ramus of the jaw and the internal pterygoid muscle until the mandibular spine is felt. Thereupon the nerve is hooked forward by a blunt hook, isolated from its accompanying vessels, divided and both ends avulsed, or a piece resected.

From the *outside* we may expose the nerve by an angular *incision* of 3 cm. ($1\frac{1}{4}$ in.) upward and 5 cm. (2 in.) forward *from the angle* of the jaw. The periosteum of the borders of the ramus is divided to the same extent and then stripped up from the inner surface until the mandibular spine is reached. Again, it may be exposed by *resection of the angle* or posterior border of the ramus of the jaw, or by a horizontal incision over the middle of the ramus, retracting Stenson's duct upward, separating the fibers of the masseter vertically, dividing the periosteum in the same line, and *trephining* or chiselling through the *centre of the ramus.*

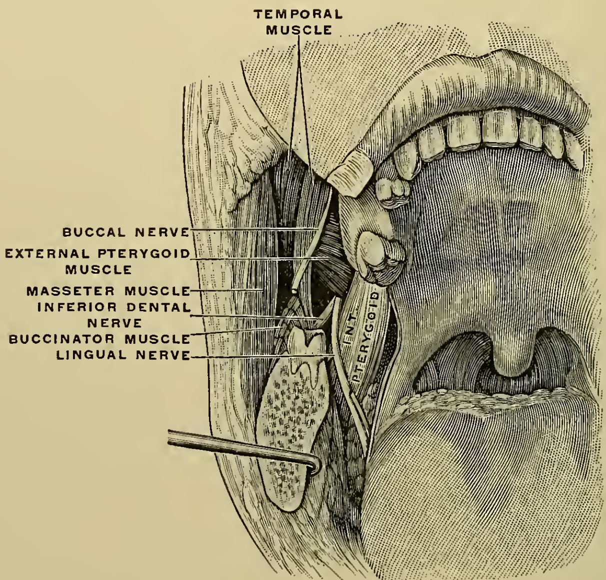
The **buccal nerve** (Fig. 35) is another sensory branch of the fifth nerve, sometimes affected by neuralgia, which is felt in the skin and mucosa of cheek and lips. It may be *exposed from within* or without the mouth. As the nerve courses forward on the inner surface of the temporal muscle, near its insertion on the coronoid process, it is only *covered on its buccal surface by* the mucous membrane, buccinator muscle, and fatty tissue, so that it may be exposed by dividing the latter layers vertically behind the last molar. *From the outside* it may be exposed by a transverse *incision* of 5 cm. (2 in.) over the course of Stenson's duct (see p. 98), which with the accompanying nerves is retracted upward or downward. The fatty tissue (Bichat's lobule) between the buccinator and masseter is removed or retracted, and the nerve is seized opposite the insertion of the temporal muscle, about 2.5 cm. (1 in.) behind the anterior border of the masseter. When the neuralgia involves several branches, or shifts from one to another, or recurs after peripheral operations, a central involvement is indicated and the Gasserian ganglion or its sensory root should be resected (p. 39).

In any *operation on the face transverse incisions* are preferable and vertical incisions objectionable because of the danger of wounding important structures having a transverse course. These are the branches of the facial nerve, already mentioned, and the duct of Stenson, whose course is given below. This, the excretory duct of the parotid gland, is beneath the **deep fascia**, which forms the next of the several layers of this region. This fascia is continued forward from the parotid gland, of

which it forms the sheath. The two layers of the parotid sheath unite and form the fascial covering of the masseter and, in front of this, of the buccinator. Beneath the masseteric fascia lie the branches of the facial nerve which (except the buccal branches) pierce it at the anterior border of the muscle.

Stenson's Duct.—Stenson's duct, 3 mm. ($\frac{1}{8}$ in.) in *diameter, extends* forward for 5 to 6.5 cm. (2 to $2\frac{1}{2}$ in.) from the anterior border of the parotid gland to the *opening* of the duct on the buccal mucosa, *opposite* the crown of the second molar tooth, 4 mm. ($\frac{1}{6}$ in.) below the reflection of the mucosa from the gums to the cheek and about 33 mm. ($1\frac{1}{3}$ in.) behind the angle of the mouth. **The course** of the duct is a finger's

Fig. 35



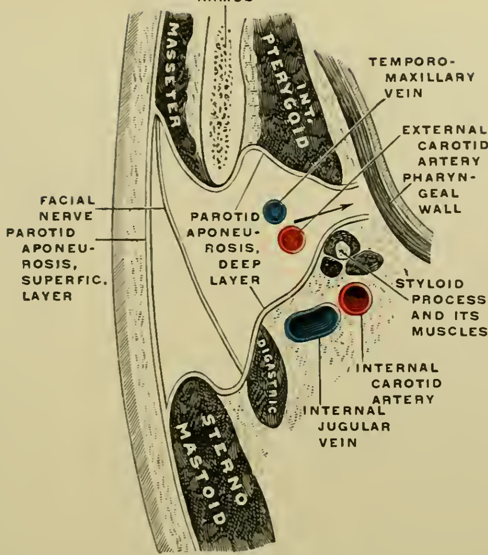
Zygomatic fossa and adjacent parts as seen when exposed from the vestibule of the mouth. (Zuckerkandl.)

breadth, or 18 mm. ($\frac{3}{4}$ in.), below the zygoma or in a line from the lower end of the concha of the ear to the midpoint of the upper lip. The posterior or *masseteric portion* crosses the middle of the masseter, having the *socia parotidis* above or superficial to it, the *transverse facial artery* above it, and the *buccal branch* of the facial nerve below it. It then bends sharply inward through the fat of the cheek to the buccinator muscle, through which the anterior or *buccal portion* runs obliquely forward and then for a short distance between the muscle and the lining mucosa to its termination.

The *bends* in its course should be remembered, for in passing a probe through it they should be straightened out by pulling forward the angle of the mouth. The course of the duct should be borne in mind so as to

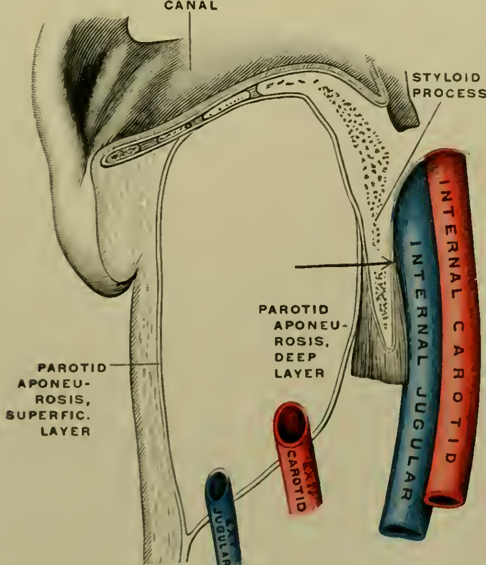
PLATE IV

FIG. 36



Horizontal Section through the Left Parotid Compartment. Diagrammatic. Arrow indicates the pharyngeal opening of the compartment. (Testut.)

FIG. 37



Frontal Section through the Right Parotid Compartment, to show its relations. Diagrammatic. Arrow indicates the pharyngeal opening of the compartment. (Testut.)

avoid it in any incision in the cheek, for its *division* may be followed by an obstinate **salivary fistula.** This is particularly troublesome in the posterior or masseteric portion where successful conservative treatment is not easy to provide except by an anastomosis between the divided ends, a difficult matter on account of its small size, or a plastic operation. In the anterior or buccal portion of the duct a salivary fistula may be successfully treated by stitching the proximal end of the duct into an opening in the buccal mucosa made by incising through the buccinator, behind its normal opening.

The duct is surrounded by a **fibrous sheath** continued forward from the parotid sheath and by a fibrous sheath of its own. Both of these sheaths leave it where it penetrates the buccinator and there become continuous with the fascial covering of this muscle. *Inflammation* may travel back along the duct to the gland from the buccal cavity in case of stomatitis or lack of cleanliness in the latter. It is not unlikely that this is the route of infection in some cases of acute parotitis complicating acute infectious diseases. Hence the importance of the care of the mouth in these conditions.

Between the buccinator and its fascia and behind Stenson's duct is a group of deep buccal or *molar glands* which may be the origin of cysts or adenoma. They are opposite the last two molars. Behind these and filling the space between the buccinator and the masseter is a *pad of fat*, the buccal fat pad or "*Bichat's lobule.*" This is quite constant, even in emaciated conditions, but if it be absorbed in wasting diseases a marked hollow of the cheek is produced in front of the masseter. A swelling, from *lipoma or abscess* in this situation, *points* in the mouth, as it is beneath the buccal fascia. In case of abscess it is to be noticed that this *fat* is *continuous* with the fat and loose areolar tissue in the temporal and zygomatic fossæ and that which covers the upper part of the pharynx. The *mucous membrane* lining the buccinator is thin and directly adherent to the muscle without submucous tissue between.

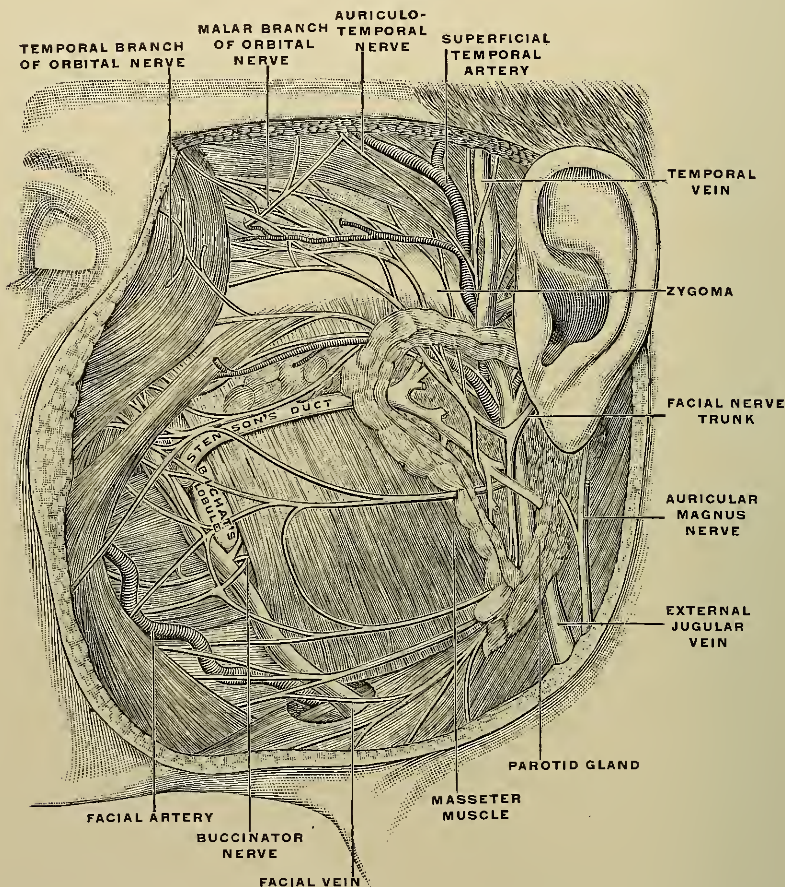
The Parotid Region.—*Superficially this is bounded in front* by the posterior border of the mandible; *behind* by the mastoid process and sternomastoid muscle; *above* by the auditory meatus, the condyle of the jaw, and the posterior part of the zygoma; *below* by a line from the angle of the jaw to the sternomastoid muscle, outlined by a thickened band of the cervical fascia. The surgical anatomy of this region is most important on account of the important parts in relation or contiguity with the parotid gland which occupies it.

This gland is *lodged* in a narrow and deep but well-defined space, **the parotid compartment,** which is *bounded* as follows: *Behind* by the sternomastoid, the posterior belly of the digastric and the mastoid process; *in front* by the posterior border of the ramus of the jaw, covered by the masseter and internal pterygoid muscles; *above* by the external auditory meatus and the posterior part of the glenoid fossa; *below* by the stylomaxillary ligament which separates the parotid from the posterior end of the submaxillary gland; *internally* by the styloid process and its muscles, which separate it from the internal carotid and internal jugular

with their accompanying nerves, and, in front of these, from the loose tissue around the pharynx.

Within these limits the parotid is enclosed within a distinct **sheath** which is derived from the deep cervical fascia. At the anterior border of the sternomastoid the fascia which has formed the sheath of that muscle again divides into two layers, one of which passes internal and the other

Fig. 38



Lateral view of the face. Superficial layer. Parotid dissected so as to show contents. (Bardeleben.)

external to the gland. These layers unite in front of the gland to become continuous with the fascia covering the masseter; and below the gland they unite along the thickened band between the angle of the jaw and the sternomastoid muscle. From this band the inner layer passes inward and upward on the outer aspect of the styloid process and its muscles, forming the sheath of these muscles and becoming attached to the styloid process.

Internally the *parotid sheath* is *deficient* in front of the styloid process, between it and the internal pterygoid muscle, where an uncovered prolongation of the gland projects inward into relationship with the pharyngeal wall, in front of the great vessels, etc. Hence *abscess or tumors* of the parotid are unopposed by the sheath in spreading inward toward the pharynx. Also in postpharyngeal abscesses there is often a parotid swelling and sometimes the abscess evacuates through the parotid. *Anteriorly* there is a process of the gland, **socia parotidis**, prolonged forward a variable distance on the surface of the masseter, above or overlying Stenson's duct, and, like the latter, covered by a prolongation of the parotid sheath. In inflammation or tumor of the parotid, therefore, the swelling may extend forward onto the surface of the masseter. *Superiorly* the *sheath* is *incomplete,* being attached externally to the inferior border of the zygomatic arch and the outer part of the cartilaginous auditory meatus, internally to the base of the styloid process, the free border of the vaginal process, and the Glaserian fissure. Hence between the outer and inner layers of the sheath superiorly the gland is in *direct contact,* without intervening fascia, with the *external auditory meatus* and the posterior part of the glenoid fossa. This accounts for the ease with which *inflammations* of the parotid *extend* to the *external auditory meatus* or the periosteum of the adjacent bones, or vice versa (see pp. 54 and 55).

As a portion of the gland occupies the posterior part of the glenoid fossa it comes in direct *relation* with the capsule of the *temporomandibular joint,* which explains in part the *pain* of moving the jaw in cases of parotid inflammation, like mumps, abscess, etc., and the occasional extension of inflammation of the gland to the joint. The pain is also accounted for by the fact that in movements of the jaw, like retraction or opening, the parotid compartment is encroached upon and the gland pressed upon by the ramus or its angle, and thus the pain of an inflamed parotid is aggravated.

The fact that the *size* of the *parotid compartment,* and especially that of its superficial boundaries, is *altered* by the position of the jaw, which occupies a groove on its anterior surface, should also be remembered in *operations* on this narrow region, in which we need all the space available. Thus, it may be *increased* anteroposteriorly by about 1 cm. ($\frac{3}{8}$ in.) by a simple protrusion of the jaw and to a certain extent by extension of the head, whereby the sternomastoid is separated from the ramus. It is *narrowed* in the opposite movements. In opening the mouth it is narrowed inferiorly but widened superiorly by the gliding forward of the condyle. The obliquity of the ramus in infancy and old age widens the lower part of the space.

The strength of the fascia superficial to the parotid offers much resistance to the spontaneous opening of a parotid abscess in this direction. In addition to the directions indicated above, an *abscess* may also *extend* downward to the neck, upward into the temporal fossa, or forward toward the buccal cavity, internal to the ramus where the sheath is weaker and is penetrated by the carotid. Pus within the gland may also occasionally escape along a vessel or nerve where it perforates the investing fascia.

From the inner surface of the enveloping fascial sheath fibrous processes extending inward divide the gland into *lobules* and support the vessels and nerves which pass through it or supply it. To these *trabeculæ* the *vessels adhere* so intimately that it is practically impossible to remove the gland and spare the vessels. Although the *nerve trunks* are less intimately adherent, yet in the living subject, especially where the entire gland is occupied by a tumor, it is impracticable if not impossible to remove the gland and spare the nerves also. This fibrous framework is the seat of the inflammation in the *specific parotitis* known as *mumps.* Acute parotitis also occurs as a *complication* in septic conditions, in acute infectious diseases, such as typhoid fever and more rarely pneumonia, and after injuries and diseases of the abdomen and pelvis. Abscess formation is to be expected in such conditions, and the pressure on the small vessels may occlude them and cause a necrosis of the lobules of the gland supplied by them.

Contained within and passing through the gland are many important structures. The **facial nerve** passes forward through the gland from the postero-internal aspect, with an inclination outward and slightly downward. Its *entry* into the parotid corresponds to the point where the anterior border of the mastoid meets the external auditory meatus. It *lies* superficial to the main arterial and venous trunks and breaks up, after an undivided course of about 2 cm. ($\frac{3}{4}$ in.), into a *plexus* which emerges at the anterior and upper border of the gland, after being joined by branches of the **auriculotemporal nerve** (see also p. 92). The latter sensory branch of the inferior maxillary division of the fifth nerve *passes* from within upward and outward through the upper part of the gland to *emerge* at its upper border. Thence it *crosses* the root of the *zygoma* between the ear and the temporal artery, where it may be exposed and resected. The *pain* of a parotitis and of some parotid tumors may be referred along the course of this nerve. The presence of the latter and of the *great auricular nerve,* supplying the gland with sensation, within the unyielding parotid fascia accounts for the severity of this pain.

The **external carotid artery** lies under cover of the ramus of the jaw up to the junction of the middle and lower thirds of its posterior border, where it enters the internal or deep surface of the parotid quite anteriorly. Thence it continues through the upper three-fourths of the gland in a direction upward, outward, and slightly backward to behind the neck of the condyle of the jaw, where, having become more superficial, it divides into its two terminal branches. These *branches,* the superficial temporal and internal maxillary arteries, together with the posterior auricular and sometimes the occipital, are within the parotid at their commencement. Within the gland the artery is *separated from the internal carotid,* and the accompanying internal jugular vein, vagus, glossopharyngeal, and sympathetic nerves, by the styloid process and its muscles, the parotid fascia, and a varying thickness of gland tissue.

It may be difficult at times to tell the *source* of *arterial hemorrhage* in a deep parotid wound. But in general, if the source of the bleeding cannot be found and both ends tied, it is best to expose and tie the external

carotid first, and then if necessary the internal carotid, not the common carotid. It is evident from its relations that the **styloid process** is a most important *landmark* in extensive operations on the parotid, for it indicates its inner boundary, the position of its prolongation toward the pharynx and of the deep vessels.

The **temporomaxillary vein** lies superficial to the artery, and usually divides within the parotid into its *two divisions,* one of which continues downward to the lower border of the gland to become the *external jugular,* while the other, passing downward and forward, joins the internal jugular. The number, size, and deep situation of the *vessels* in the narrow and deep parotid region accounts for the *gravity of wounds* of this region when one of the vessels is injured.

Both superficial to and within the substance of the gland are a number of **lymph nodes** which receive lymph from the temporal and frontal regions of the scalp, the eyelids, and root of the nose, the external auditory meatus, and perhaps the nasal fossæ. They empty into the deep cervical nodes. These lymph nodes when enlarged form one variety of parotid tumor. The sources from which they derive their lymph supply should be examined for the presence of lesions, in diagnosticating between lymphatic enlargements and other parotid tumors. *Abscess* on the surface or within the gland may be due to an inflammation of these nodes. The deep parotid nodes are found especially along the carotid artery and the temporomaxillary vein.

Tumors of the parotid are not uncommon. Mixed tumors, containing cartilaginous, myxomatous, and fibrous portions, occur quite often among them. The cartilage is derived from islands of embryonal cartilage, from the mandibular arch, enclosed within the gland. In addition there are *malignant tumors* or malignant degeneration of benign tumors. It is a striking fact that the *testes,* in which metastases after mumps are quite common, are also one of the few other soft parts where cartilage occurs in tumors. The *benign tumors* are often encapsulated and involve only a portion of the gland so that their extirpation may be readily accomplished and the *facial nerve,* perhaps somewhat displaced, may be *spared* in whole or in part. It has been much discussed whether the *entire gland* can be or should be *removed* when involved in a newgrowth, especially a malignant one. The operation is difficult, but it certainly can and should be done if the tumor is confined within the capsule of the gland. It is to be expected that the *facial nerve* must be *sacrificed,* but the result of this, I have found, is often not so distressing as might be expected. The external carotid and external jugular are tied in the earlier stages of the operation, for the bleeding is very free from the arterial branches, including the temporal, internal maxillary, posterior auricular, and transverse facial arteries and the branches supplying the gland. *Incisions* over the parotid for minor conditions should be transverse, so as to avoid the branches of the facial nerve.

The **upper and lower jaws** are both susceptible to **phosphorus necrosis** among those who work with phosphorus, as in match factories, but it is almost confined to those with carious teeth. I have also seen it in an

old colored man who took phosphorus internally for a long time to keep up his sexual vigor. There is usually an osteoplastic periostitis resulting in the production of osteophytes, which themselves are liable to necrose.

The Upper Jaw or Maxilla.—The upper jaw or maxilla is *supported* or buttressed *above and internally* by the articulation with the frontal and nasal bones, *above and externally* by the vertical portion of the malar, *behind* by the pterygoid process, *externally* by the zygomatic arch, *internally* by the articulation with the opposite maxilla in the hard palate. Thus supported, it is not very often **fractured** but it may be by direct or indirect violence. In the latter manner the shock is usually transmitted through the lower jaw as in a fall or blow, more rarely through the head while the chin is fixed, sometimes through the malar bone, which, on account of its density, is seldom fractured, but may be driven into the upper jaw. Fracture by direct violence may be due to a direct injury over a circumscribed area or to the violent extraction of a tooth. The maxilla is partly protected from direct violence by the prominence of the nose internally and the malar bone externally. When the *wall of the antrum* is fractured it may be much depressed, depending upon the direction and degree of the force. Whether it is depressed or not, *subcutaneous emphysema* may occur, and is increased on blowing the nose. In other cases *pain* referred to the dental or infra-orbital nerves may lead to the diagnosis. In more than one case my attention has been called to a fracture through the infra-orbital margin and canal by pain in the nerve.

Although the maxilla is very *vascular*, yet its periosteum, like that of the skull, is not likely to form new bone, so that there is no reproduction after necrosis. The infra-orbital margin is the favorite site of *tuberculous periostitis* and osteomyelitis of the maxilla.

The fact that the maxilla is *connected* with the surrounding bony parts at *four points* is important to remember in its **excision**, which is undertaken in case of malignant tumors, etc. (1) The connection with the *malar bone* is divided by a wire saw passed through the forepart of the sphenomaxillary fissure after raising the periosteum of the orbital floor. (2) The *nasal process* and orbital surface of the maxilla are divided by the bone forceps whose blades are introduced into the nasal fossa and the orbit below the tendo oculi. In some cases most of the orbital floor may be left, the section passing just behind or sometimes below the orbital margin. The orbital plate may often be best divided by a fine chisel. (3) The *hard palate*, by which the opposite maxilla and palate bones are connected together, is divided by a saw or bone forceps after extracting a central incisor and dividing and stripping up the mucoperiosteum on its under surface. (4) Its connection behind with the *pterygoid process* and the intervening palate bone, as well as with muscular attachments (external pterygoid), are freed by twisting the bone, to *avoid* unnecessary injury to the branches of the *internal maxillary artery*. Before this last step in the removal of the jaw it is well to *cut* the *infra-orbital nerve* at the back of its groove in the floor of the orbit and to divide the connection of the *soft palate* with the back

of the hard palate on the affected side. The bony connections are divided in the order named.

To *expose* the maxilla *for excision* the soft parts are divided down to the bone along the lower margin of the orbit to the side of the nose, thence in the groove between the nose and the cheek and the nose and the lip to the ridge on the side of the filtrum of the lip and down this ridge through the lip. In this *incision* the following *nerves and vessels* are *cut* in the following order from above downward; the palpebral branches of the infra-orbital vessels and nerve, angular artery and vein, lateralis nasi vessels, nasal branches of the infra-orbital nerve, and the superior coronary vessels. Several small branches of the facial nerve may also be cut. Notice that *no large vessels* are *divided* in the soft parts, and the same may be said of the bone section, though the operation may appear bloody from the many small branches divided. The attachment of the lateral cartilages of the nose to the bone are divided, to open up the anterior nasal orifice. The *flap* is then *turned back*, keeping close to the bone if the soft parts are not involved, and in any case taking care to keep the *facial artery* and vein intact in the flap and to *avoid Stenson's* duct. The latter may be avoided by remembering its course and dividing the mucous membrane close to the gums so as to avoid the orifice of the duct, 4 mm. from this point.

The division of the *mucous membrane* may be left toward the last to avoid the flow of blood into the mouth. In rare cases, but not as a rule, the mucoperiosteum of the palate may be spared by dividing it close to the alveolar margin, stripping it up, and subsequently suturing it to the mucosa of the cheek, thus roofing over the oral cavity. The *skin flap* is *well nourished* by the facial and transverse facial vessels and is supplied by the facial nerve. The *scar* is almost imperceptible in time. By stripping up the periosteum of the orbital floor the *contents of the orbit* are spared, but the origin of the inferior oblique muscle is detached. The attachments of the lateral expansions of the orbital aponeurosis, forming the suspensory ligament of the eyeball, should be spared. In dividing the nasal process of the maxilla and the lacrymal bone the *lacrymal sac* or the *nasal duct* will be *cut* across. If the nasal process is removed high up the origin of the tendo oculi is included. In the last step of twisting off the maxilla the *descending palatine artery* and great palatine nerve are severed. In some cases where the tumor involves only a part of the maxilla, most commonly the alveolar process, the excision may be partial, sparing in such a case the orbital floor and margin.

Again, *temporary resection* of the *maxilla* is practised to gain *access to the nasopharynx*, to remove polypi situated there. Partial resection, sparing either the orbital plate or the palate and alveolar arch, gives a better exposure and is preferable. In Langenbeck's temporary resection the *alveolar arch* and *palate* are left *undisturbed*, the section passing into the nose above them; the connection with the malar bone is severed and, after another horizontal section is made from the orbit to the nasal fossa, the bone flap, only attached to the nasal bone, is *turned inward* as on a hinge, and is replaced at the end of the operation.

The Lower Jaw or Mandible.—The lower jaw or mandible is more often **fractured** than any other bone of the face, in spite of its density, its free mobility, the buffer-like interarticular cartilages, and its horseshoe shape, which gives it increased elasticity. It may be broken by *direct or indirect violence.* In the latter case the pressure either increases or flattens the curve until it *gives way,* usually at its *weakest point* about 3 cm. ($1\frac{1}{4}$ in.) from *the symphysis,* where the presence of the mental foramen seems to cause a weakness. It is more often fractured by *direct violence,* and in this case also most often where it is weakest *near the symphysis.* The *line of fracture* may be nearly vertical, especially when at or near the symphysis, or more oblique, in most cases of fracture farther back.

The *displacement* depends upon the position and direction of the fracture and the direction of the force. In general the elevator muscles attached to the ramus draw the *posterior fragment* upward, forward, and outward, while at the same time gravity and the depressor muscles, digastric, mylohyoid, and geniohyoid, draw the *anterior fragment* backward, downward, and inward. In case of a *fracture of the ramus* itself the muscles attached to it hold the fragments together. In *double fractures,* which are quite common, the intermediate fragment may be displaced downward and backward. The displacement in fractures of the body of the bone is usually plainly visible in the difference of *level of the teeth.* The neck of the *condyle* is occasionally broken on one or both sides by direct blows or blows on the chin. In such cases the condyle may be drawn forward by the external pterygoid and the lower fragment pulled upward by the other muscles of mastication. I have seen an oblique fracture of the ramus running from behind downward and forward and separating the region of the *angle* from the rest of the bone. Fractures of the alveolar process are common in connection with pulling teeth.

Although, owing to the firm character and close attachment of the gums to the bone, fractures of the body of the lower jaw are almost always *compounded* in the mouth, and are thus exposed to bacterial infection, these fractures generally do well if the mouth is kept clean and they are kept in good *position.* This we may accomplish by splinting the lower against the upper jaw by the pressure of bandages, preferably with an *interdental splint* intervening. A fracture posterior to the mental foramen may injure the *inferior dental nerve* so as to be very painful and sometimes to cause anesthesia of the lower lip and chin, supplied by its mental branch. The nerve escapes injury more often than one would suppose, and only in rare instances has it been compressed later on by the callus.

Speech is interfered with on account of the attachment of the muscles of the tongue and the floor of the mouth to the jaw. If the attachment of the genioglossus is displaced backward in a fracture on either side of the symphysis, or is divided in excision of the jaw, some trouble may be experienced from the *tongue falling backward* and blocking the pharynx.

The *lower* like the upper *jaw* may be the seat of *malignant tumors,* especially sarcoma, which, as well as extensive necrosis, may call for **excision** of half of the jaw, more or less. Excision of the entire jaw is

rarely required. In excising *half of the mandible* an *incision* is made down to bone along its lower border, commencing a little beyond the median line. It is not necessary to extend it up the back of the ramus, and if this is done it should not extend more than 2 cm. ($\frac{3}{4}$ in.) for fear of wounding the facial nerve or even Stenson's duct. Except in large tumors it is not necessary to incise vertically through the lower lip, and even then not through the vermilion border.

The horizontal *incision divides* the facial vessels at the antero-inferior angle of the masseter, also some branches of the facial and superficial cervical nerves. If the lip is incised in the median line the anastomoses between the inferior coronary, inferior labial, and submental vessels of the two sides are divided. The bone is then freed of its muscular attachments, keeping close to the bone. Except when there is a malignant growth, which has reached to or developed from the surface, the jaw may often be excised *subperiosteally*, largely by blunt dissection. In this connection Tillaux has called attention to the importance and the feasibility of preserving the periosteum covering the angle and adjoining parts which connect together the attachments of the masseter and internal pterygoid muscles. The *entire jaw* has been *reproduced* after subperiosteal removal.

It is sometimes difficult, even with much depression, to free the attachment of the temporal muscle which, it should be remembered, is attached to the margins and the inner surface of the *coronoid process*. In such cases the latter may be cut off with the bone forceps in place of detaching the muscle. As to the *condyle* it is best at the last to twist it off instead of cutting the capsule and the insertion of the external pterygoid, on account of the danger of wounding the internal maxillary artery as it winds around the neck of the condyle. The *inferior dental vessels and nerve* and their mylohyoid branches are of course divided close to the inferior dental foramen. In *large tumors* care should also be taken to *avoid* the salivary glands, the external carotid artery, the temporomaxillary vein and the lingual and auriculotemporal nerves. *Cysts and tumors* of the jaws may also develop from the tooth germs (see p. 114). In a *central sarcoma* or other tumor *pain* from pressure on the dental nerves may be one of the earliest symptoms noticed. *Congenitally* the jaw has in rare cases been cleft at the symphysis, incompletely formed, or entirely absent, depending upon defective development of the mandibular arch.

Temporomandibular Joint.—The **condyle** can be *seen* and *felt* as a slight *projection* immediately in front of the tragus of the ear, from which point it can be seen and felt to move forward and downward onto the articular eminence when the mouth is widely opened. In *dislocation* the condyle slips forward and upward from the eminence into the zygomatic fossa. The *depression* which is seen and felt, in place of the normal projection, in front of the tragus is a valuable sign of dislocation, especially when it is unilateral. The *bony external auditory* canal is immediately behind the joint, and in falls or blows on the chin the condyle may be driven upward through the glenoid fossa, fracturing the base of the skull, or backward, fracturing the anterior wall of the canal. Only in the latter

way is a posterior dislocation possible. The *direction* of the fibers of the only strong ligament of the joint, the *external lateral,* is downward and backward, so that it resists the backward movement of the condyle and thus protects the wall of the canal from more frequent injury.

Dislocation of this joint is permitted in the *forward* directly only, with the above exception. It *occurs* only when the *mouth is widely open,* in which position the external lateral ligament is relaxed and the condyle is on the eminentia articularis, from which it is pulled forward by the vigorous contraction of the external pterygoid in *violent yawning,* laughing or vomiting, in dentists' operations, and in the violent introduction of large objects into the mouth. When the *condyle* is pulled in front of the articular eminence it *glides upward* and forward along the inclined surface in front of the eminence and is pulled up by the elevator muscles, especially the deep posterior vertical fibers of the masseter. The jaw, however, cannot be closed, but is *held widely open,* and the fixity of this position and the difficulty of reduction is explained in different ways.

1. The *direction* of the fibers of the *external lateral ligament* is *reversed* in the new position of the condyle, and the attempt to close the jaw now puts this ligament on the stretch. The same is true of an attempt to push the jaw backward, for it has to pass downward to pass beneath the articular eminence. A *downward* as well as *backward pressure* is necessary *in the reduction* of the dislocation, and this can be effected with the least tension and resistance of the external ligament if the jaw is at first kept widely open, or even opened more widely. When the jaw is not dislocated it is not true, however, as is sometimes stated, that the external lateral ligament is relaxed when the mouth is wide open, but rather the reverse, for the ligament is tightened by depression of the jaw and by the downward gliding onto the articular eminence more than it is relaxed by the forward movement of the condyle.

2. In the combined hinge and sliding movement of the jaw the condyle moves forward, the angle backward, and the **axis of motion,** or the part which moves least, is about the centre of the ramus, or at the inferior dental foramen. Hence the vessels and nerves which enter this foramen are not subject to traction and displacement, as they otherwise would be. The **line of action** of the masseter and internal pterygoid muscles normally passes upward and forward in front of this axis. When, however, the jaw is dislocated forward the line of action of these muscles is displaced somewhat backward with the angle, while the axis of motion is displaced in front of it (Fig. 39). Hence, while normally the action of these muscles is to elevate the front of the jaw and depress the angle, in a dislocated jaw their action is reversed so that they open the jaw and keep it open. That the *muscles* are *spasmodically contracted,* from their being injured or put on the stretch or from pressure or traction on their nerves, can be readily felt on the patient. According to Tillaux, a dislocation is produced when in a violent opening of the mouth the axis of motion is carried in front of the line of muscular action. In a dislocation the condyle may be said to be held by a balance of forces between the external lateral ligament pulling upward and backward and the muscles pulling

upward and forward. (3) It is possible in rare cases, as in the specimen in the Musée Dupuytren, that the apex of an unusually *long coronoid process* may be caught against the malar bone and resist reduction. The fibrocartilage may occasionally prevent complete reduction by blocking the glenoid cavity; it is not the cause of the fixation of the jaw.

In dislocation the *fibrocartilage* may, in rare instances, pass forward with the condyle, but it usually remains behind in the glenoid fossa, and in the latter case the *anterior part of the capsule* may be torn. The dislocation may occur on one or both sides.

The lower jaw is sometimes held *firmly closed*. This may be due to a tonic spasm of the muscles of mastication, a condition known as **trismus or lockjaw**. This may be an early symptom of *tetanus* or a *reflex*

Fig. 39

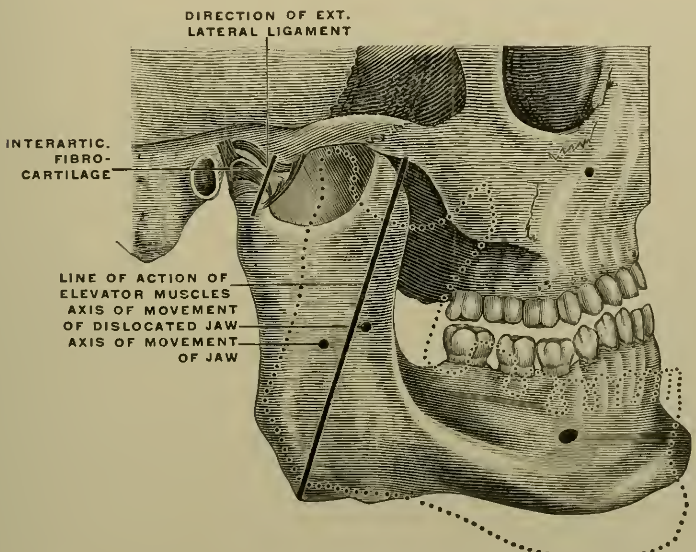


Figure to show the relation of the line of action of the masseter and internal pterygoid muscles to the axis of movement of the lower jaw in its normal position and in dislocation. The dotted line represents the position of the dislocated jaw. (Tillaux.)

symptom due to the irritation of one of the sensory branches of the fifth nerve, especially those of the lower teeth. The *nerve* to the *muscles* which close the jaw is the only motor branch derived from the fifth nerve.

Again the *firm closure* of the jaw may be due to a *cicatricial contraction* following a cancrum oris or other large loss of substance of the cheek or to an *ankylosis* of the temporomandibular joint from rheumatic or septic (especially gonorrheal) synovitis. In ankylosis an excision of the neck of the condyle is done to secure a false joint.

The **two lips** unite laterally at the *commissures* to enclose a transverse aperture (*the buccal orifice*) popularly called the mouth, but the latter term strictly applies to the cavity to which the opening leads. The lips consist of the *following layers:* (1) Skin closely adherent to (2) a mus-

cular layer (orbicularis oris), (3) labial mucous glands among which are the coronary vessels, and (4) mucous membrane.

The **thick skin** joins the mucous membrane along the free border by an intervening *"vermilion border,"* or dry mucous membrane, which is remarkable for its *sensitiveness* and the frequent occurrence of *epithelioma* at the line of junction, especially on the lower lip. The color of this border indicates the condition of the blood and the circulation, save in those much exposed to the weather. This border on the upper lip presents a median tubercle, the remains of the free extremity of the frontonasal process. From this tubercle up to the columna nasi is a shallow groove, the *filtrum,* bounded by two low ridges, along which vertical incisions are carried if it is desired to show as little scar as possible.

The **muscular fibers** run mostly parallel with the buccal orifice, hence *incisions* to open abscesses, etc., should be *horizontal,* for a vertical incision is followed by considerable retraction of the edges. Into the orbicularis oris are inserted most of the muscles of expression.

The **glandular layer** is formed of racemose glands resembling the salivary glands. It may hypertrophy, as a whole, thickening the lip, or the individual glands may form retention cysts. On a vertical section of the lips this layer protrudes, while the muscular layer retracts. The **coronary arteries** are embedded in this layer close beneath the mucosa and nearer the free than the attached margin of the lips, about 12 mm. ($\frac{1}{2}$ in.) from the former. *Bleeding* from them may be easily *prevented or stopped* by pressure of the fingers or a temporary ligature. In *suturing* vertical incisions of the lip, as in harelip operations, one suture should be passed behind both ends of the artery, between it and the mucosa, to check the hemorrhage. The coronary arteries can retract freely into the loose tissue in which they lie, so that bleeding is often spontaneously arrested. As the superior coronary artery sends a branch to the septum nasi, *compression* of the artery may *check nose bleed.* The *vascularity* of the lips, from the coronary and other arteries, accounts for the frequent presence of nevi and other vascular tumors, as well as for the ready *healing* of the many plastic operations performed to relieve deformities and fill the gaps left by the removal of newgrowths about the mouth. The success of these operations is also favored by the laxity and mobility of the tissues about the mouth. The vessels of the two sides of the lips *anastomose* freely, hence *both ends* of a divided vessel should be *tied.* The connection of the veins, through the facial and ophthalmic, with the cavernous sinuses should be remembered in inflammatory conditions of the lips, especially the upper lip.

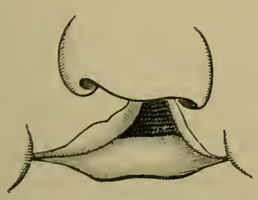
The **lymphatics** pass to the submaxillary and submental nodes, so that these nodes may be involved and require removal in *epithelioma* of the lip. As the subcutaneous lymphatics of the two sides of the lower lip frequently cross or anastomose across the median line, the nodes of both sides are liable to be infected. The **nerves** of the upper lip come from the second division (infra-orbital), those of the lower lip from the third division (inferior dental) of the fifth nerve. There are numerous end bulbs resembling tactile corpuscles in the sensitive vermilion border. In the

distribution of the labial nerves, from the second and third divisions of the fifth pair of nerves for the upper and lower lips respectively, a crop of herpes (*herpes labialis*) often appears, of neurotic or digestive origin.

The **mucous membrane**, reflected onto the gums above and below, at the attached margin of the lips, presents on each lip a small median fold or *frenulum*, of which the upper is the larger. In extensive *plastic operations*, as after the removal of a large epithelioma of the lip, it is essential for a good and permanent result that the *flap* should be *lined by mucous membrane*, otherwise it becomes adherent to the jaw and immovable and does not oppose the dribbling of saliva. In case the newgrowth is smaller a V-shaped incision with suture of the edges suffices.

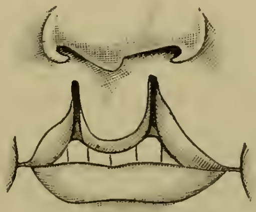
Development.—In the fetus near the end of the second week the buccal and nasal cavities are one, bounded above by the frontonasal process, laterally by the superior maxillary processes, and below by the mandibular processes of the first visceral arch. These two cavities are separated by the fusion of the median frontonasal and the laterally placed superior maxillary processes to form the upper lip and palate, as well as the upper part of the face.

Fig. 40



Complete lateral harelip.

Fig. 41



Double harelip.

The *lower lip* is formed by the median fusion of the coverings of the lateral halves of the mandibular or first visceral arch. Failure of this fusion, resulting in a median cleft of the lower lip, is very rare and only a few instances of it are on record.

Failure of the fusion on one or both sides of the frontonasal process causes **single or double harelip** respectively. Hence this is *lateral and not median*, a median cleft, like that of the hare, being very rare and otherwise formed. Harelip is more often *single* and on the *left side*, and is commoner in males. It may involve part of the lip only or extend up into the nostril. In the latter case it is often combined with a *cleft* of the *alveolar arch* or of the *palate* as well.

In **double harelip** the central insulated part of the lip often appears as a nodule attached to or suspended from the nose, for it is protruded by the premaxillary bone, which projects forward at the end of the vomer. This condition is due to the fact that the premaxillary bone, the septum of the nose, and the central part of the lip are formed by the frontonasal process. In **single harelip**, or on one side of a double harelip, there may be a *projection* of the *alveolar arch* on the median side of the cleft, making its closure more difficult, so that this projection should first be reduced.

The *cure* of harelip by **plastic operation** is very satisfactory. The two halves of the lip must first be freed from the maxilla, to which they are unusually adherent, the edges freshened in one of several ways, and then sutured.

Transverse facial clefts, due to failure of fusion of the mandibular arches and the superior maxillary process, commence at the corners of the mouth and cause an enlargement of the latter (*macrostoma*). The opposite condition, or *atresia* of the buccal orifice, occurs when the fusion exceeds the normal limits or it follows contraction due to pathological processes, such as burns, or faulty plastic operations. It may also be relieved by operation.

When the jaws are closed there exists between them and the cheeks and lips a space known as the **vestibule of the mouth.** The *circumference* of this space is *bounded* by the reflection of the mucous membrane from the gums to the cheeks and lips. Through this reflection we may *incise* to expose the infra-orbital and mental nerves and to open the antrum, as described above. It is near this line of reflection that we find the *abscesses* which are developed from a fistulous tract leading from a diseased root of a tooth. Such an abscess may be seen, if within the vestibule, or felt if just beyond. At the back of the vestibule, behind the last molar, is a space usually large enough for the passage of a feeding tube in case of trismus; and in addition liquids can trickle through the interstices between the teeth. The *anterior border* of the *coronoid process* can be *felt* plainly at the back of the vestibule. In *dislocation* it is much more appreciable, and its prominence may be an aid to diagnosis. In addition, as this border passes down onto the body of the jaw, external to the alveolar process, it forms a kind of *shelf* outside of the last molars, on which we may make pressure with the thumbs in reducing a dislocation of the jaw, and thus avoid the danger of being bitten when the jaws close with a snap on reduction. The *duct of Stenson* opens into the vestibule (see p. 98).

The Gums.—The gums, formed by the closely united *mucous membrane* and *periosteum* covering the alveolar processes, are dense, firm, and vascular, though paler in color than the adjacent mucosa. As the periosteum of the gum is continuous with that lining the sockets of the teeth, inflammation originating in the socket from a carious tooth may extend up and out of the socket beneath the periosteum and form a subperiosteal *alveolar abscess* or "gumboil." The latter may also occur more superficially in the tissue of the gums. The pain is considerable, as the pus is bound down by the dense gums. A similar inflammation may burrow through the bony wall of the socket and appear beneath the gums a little farther from the alveolar margin (see above). In either case the abscess may open or be opened here and go no farther, or it may extend widely beneath the periosteum and cause a *necrosis of the jaw.* If the end of the root socket of a tooth is beyond the limit of the gums, or if the pus can gravitate beyond it, the abscess is likely to break through into the cheek instead of through the gums. *Ulcerated teeth* are the *common cause of necrosis* of the jaws and should be suspected in case of swelling, abscess,

or fistula of the lower face and submaxillary region. A similar *inflammation* in the sockets of the *upper molars* may spread to the *antrum* and be the cause of an *empyema* there.

The gums covering the outer and inner surfaces of the alveolar process are continuous in the interstices between the teeth and are normally closely *adherent* to the *neck of the teeth*, thereby helping to hold them in, so that when the gums are detached the teeth are more liable to become loose. From the gums are developed a class of *tumors* called **epulis**, which may be a simple fibroma of the gums or a sarcoma developed from the periosteum. The latter form requires the removal of the adjacent portion of the alveolar process to avoid recurrence.

In **old age** as in **infancy** the gums cover the upper border of the jaw; in the former case they are very thick and hard, so as to allow a certain amount of mastication; in the latter case they may become much inflamed and cause much reflex irritation during the eruption of the teeth, so as to require "lancing" the gums. In **mercurial poisoning** and in **scurvy** the gums are characteristically congested and spongy, so that they bleed readily and may become ulcerated. Such inflammation of the gums (gingivitis) may spread to the mucosa of the entire oral cavity (stomatitis). In children crowded in large institutions such inflammation, originating perhaps in the lack of cleanliness of the teeth at their junction with the gums, may go on to the destruction of more or less of the alveolar process. In chronic **lead poisoning** a blue line of sulphide of lead may appear along the dental margins of the gums, due, it is said, to the action on the lead of hydrogen sulphide formed by the decomposition of food debris about the teeth, if the latter are not kept clean.

The Teeth.—It is impracticable to try to remember the time of eruption of each of the *twenty temporary* and *thirty-two permanent teeth*. The **order of appearance** is much more regular than the exact time, which is liable to much variation. The **temporary teeth** appear in the *following order:* lower central incisors, upper incisors, lower lateral incisors and the four anterior molars, the four canines, and, finally, the four posterior molars. The *first dentition* usually *begins* in the seventh month and is *completed* at the age of two or two and one-half years. The lower teeth appear before the upper. In rare instances a child is born with teeth. *Syphilitic children* are rather prone to early dentition and early decay of the teeth. Dentition is often delayed in *rickets* and still more so in *cretinism*, and it may be said to go on in a manner corresponding to the ossification of the cranial bones.

In the **permanent set** a *similar order* is followed except that the first molars (*six-year molars*) are the first to appear, usually in the seventh year. The second molars (*twelve-year molars*) appear from the twelfth to the fifteenth year, the third molars, or wisdom teeth, from the seventeenth to the twenty-fifth year, or they may never appear, in which case they may lead to the formation of *cysts* of the jaw. It is to be noticed in both sets that the *canine teeth* appear after those on either side of them, so that the alveolar arch may need to be spread to make room for them.

Certain **tumors** and **cysts** (*odontomata*) of the jaws are produced by aberrations of any or all of the embryonic parts concerned in the production of a tooth at any stage of its development (Sutton). They form tumors within the jaws of a fibrous, epithelial, or bony structure, according to the period of their development or the part of the tooth germ from which they spring. Odontomata only require enucleation, and not resection of the jaw.

The **enamel** of the teeth is *developed* from the epithelium of the margin of the gums which, becoming thickened, dips into the substance of the gums as the "*dental shelf,*" and forms as many epithelial caps or *enamel organs* as there are to be teeth in each set. Those of the *permanent set* lie *behind* those of the temporary set. From the dental shelf or enamel organs are formed the *epithelial odontomata.* The rest of the tooth grows up as a small papilla beneath the enamel organ, and finally becomes capped by it, the whole being enveloped in a sac (tooth sac).

The *incisor teeth* of the *permanent set* present certain *peculiarities* in many children having *hereditary syphilis.* The characteristic or **"test teeth" of Hutchinson** are the upper central incisors which present a single *crescentic notch* in the centre of the free edge. These syphilitic teeth are often short, thick, and tapering. The teeth of the upper and lower jaws are supplied by branches of the second and third divisions of the fifth nerve respectively, and irritation of these nerve endings, as in dental caries and exposed roots, may give rise to reflex facial neuralgia or be the starting point of true tic douloureux.

The Floor of the Mouth.—The **mylohyoid muscle** forms the **diaphragm** or muscular floor of the mouth, separating the buccal cavity from the neck. All *tumors or abscesses* developed above this muscle project or point into the buccal cavity and may be operated upon by that route; while those developing below the muscle present in the neck and may best be reached through an incision there.

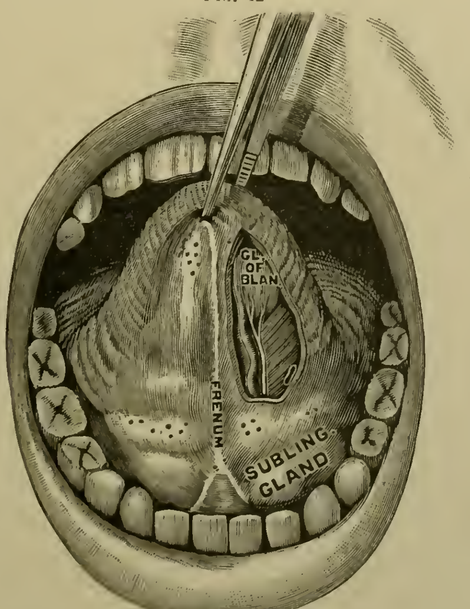
The Tongue.—The tongue occupies the greater part of the floor of the mouth. Between the interlacing *muscle fibers,* of which the tongue is composed, is a comparatively small amount of connective tissue. It is noteworthy that cellulitis or inflammation of this tissue (*glossitis*) is uncommon; but when it does occur the tongue may swell greatly so as to threaten asphyxia by pressing down the epiglottis. Owing to the firm texture of the tongue and its thick mucosa, *abscess* in its substance feels like a solid tumor. *Foreign bodies* may easily become embedded in the tongue.

The tongue is not *attached* or anchored by ligaments, but *by its extrinsic muscles,* to the mandible by the genioglossi, to the styloid process by the styloglossi, and to the hyoid bone. Hence **in anesthesia,** when the *muscles become relaxed,* the tongue is liable to drop back by its own weight and press down the epiglottis so as to close the opening into the larynx. This tendency may be *diminished* by placing the patient's head on the side, so that gravity does not tend to force the tongue backward; or it may be *counteracted* by pulling the tongue forward either directly, by the tongue forceps, or indirectly, by protruding the jaw, by

pressing forward *behind the rami,* and thereby pulling the tongue forward by the genioglossi.

The tongue normally overhangs the entrance of the larynx, thereby hiding it; hence if the tongue is drawn too far forward it exposes the larynx and favors the passage of food or other fluids into it. Similarly, when, in operations on the tongue or in excision of the forepart of the lower jaw, the genioglossi muscles are divided the tongue is liable to drop back if the patient lies upon his back. Hence precautions are taken to have the patient lie upon the side, to fasten the tongue forward by suturing its base to the mental region, and to thread the tongue with a silk suture, whereby it may be pulled forward as occasion requires, until adhesions form which fasten it in position.

Fig. 42



Under surface of the tongue and the sublingual space, showing openings of salivary ducts. The mucosa of the left side is partly removed, and shows the ranine artery and the lingual nerve. (Gerrish, after Testut.)

The tongue is also connected by mucosa with the alveolar arch and by folds of mucous membrane with the epiglottis, the soft palate (enclosing the palatoglossus muscle), and the back of the symphysis of the jaw. The latter is a median fold known as the **frenum linguæ**, which normally ends some distance short of the tip of the tongue. In rare instances this frenum extends to the tip, or is abnormally short, so as to restrict the movements of the tongue. This condition of **"tongue-tie"** may prevent the infant from sucking well or, later in life, interfere with articulation and necessitate *division* of the frenum. This may be done after lifting the tongue by the fingers or the back end of a grooved director, the

notch in which is made for the purpose. In such cases the *free edge* of the frenum should be *divided close to the jaw,* so as to avoid the ranine veins on the under surface of the tongue, and the frenum may then be torn loose as much as required. If there is any bleeding in such cases it is encouraged and not checked by the infant's nursing.

The **ranine veins** just mentioned are plainly seen beneath the mucosa of the under surface of the tongue, less than 12 mm. ($\frac{1}{2}$ in.) from and on either side of the frenum. The **ranine arteries** lie a little more laterally and more deeply placed, beneath fringes of mucous membrane which converge toward the tip.

Surface of the Tongue.—It is the bright-red color of the fungiform papillæ, scattered along the sides and tips of the tongue, contrasted with the coating of the rest of the tongue, which produces the so-called "*strawberry tongue*" of scarlet fever. The *coating* of the tongue is composed of a mixture of desquamated epithelium, food debris, and bacteria. Behind the circumvallate papillæ there is much *lymphoid tissue* in the mucous membrane. This is collected into rounded masses which are sometimes hypertrophied to form an irregular nodular mass known as the **lingual tonsil,** which may require removal on account of its impairing the movements of the glottis or causing an irritating cough. The *foramen cecum* at the apex of the circumvallate papillæ represents the upper end of the lingual or **thyroglossal duct.** In connection with a bilobed mass at the lower end of this duct the greater part of the thyroid gland is developed. Except in rare instances the thyroglossal duct disappears. From or contiguous to this duct there occasionally develops a *tumor* of the base of the tongue resembling the thyroid gland in structure. *Mucous cysts* are sometimes developed from the mucous glands which abound over the posterior third of the tongue.

The *surface epithelium,* owing to chronic irritation or inflammation, may become thickened in the form of dense opaque plaques. This condition, variously known as psoriasis, or *ichthyosis linguæ,* leukoma, and smoker's patch, is important, as it may develop into **epithelioma,** which is common in the tongue, especially on the side of the anterior half. *Tuberculous* or *syphilitic ulcers,* which also occur on the tongue, may sometimes be mistaken for it.

The **treatment of epithelioma** is **excision of the tongue** by one of the various methods employed, through the mouth or from beneath the jaw, and with or without previous ligature of the lingual arteries in the neck (see p. 138). In operating through the mouth more room is obtained by stretching the mouth, splitting the cheek, or dividing the jaw.

Hemorrhage is the chief obstacle in operating through the mouth. It is not the amount but the locality of the bleeding and the danger of its running back into the larynx and trachea that concern us. Hence the value of *preliminary ligature* of the *linguals* in the neck. Some bleeding still occurs on the stump, especially if the tongue is divided far back. This comes from the *dorsalis linguæ* branches, which are not shut off by the ligature, and from small anastomosing vessels of the ascending pharyngeal and the tonsillar branches of the facial arteries. Bleeding

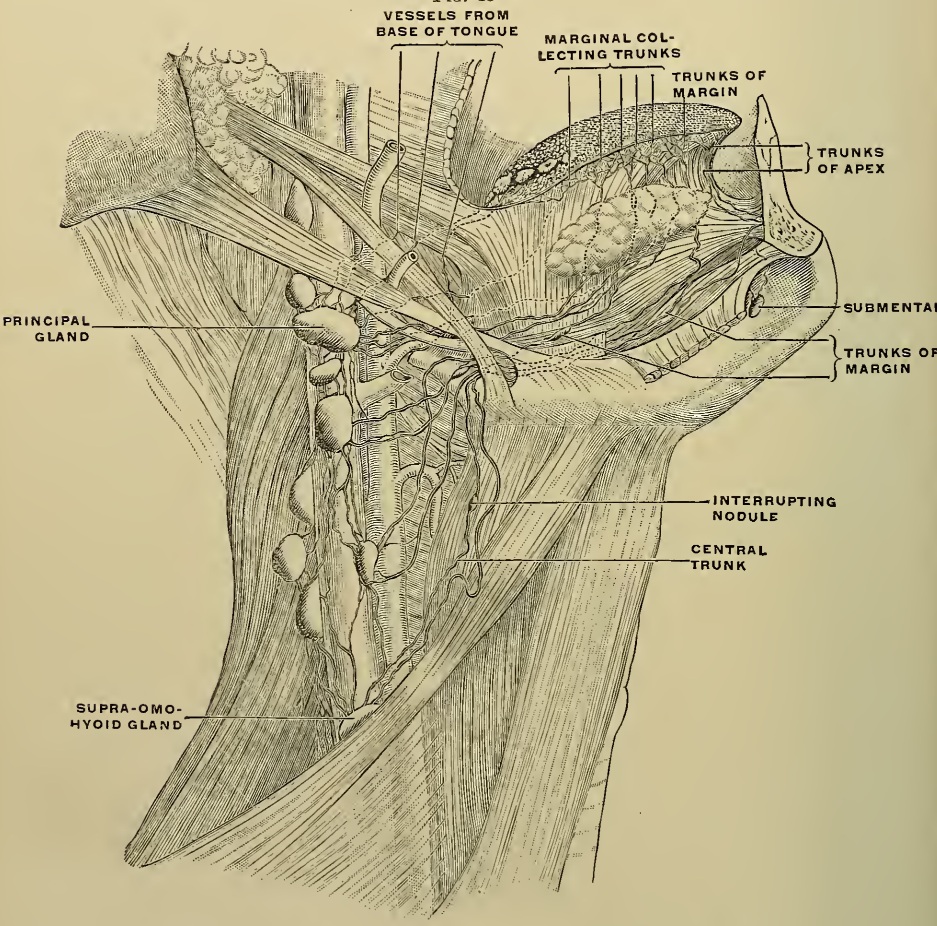
from the stump can be arrested and the stump brought well up to view by pressing up the floor of the mouth by the fingers applied between the jaw and the hyoid bone. If the *operation* is limited to *one side,* it is only necessary to ligate the lingual on that side, for there is but little anastomosis across the rather incomplete median fibrous septum of the tongue. The two ranine arteries *anastomose* by a small loop near the tip of the tongue, otherwise only by capillary branches, except in the rare cases where the principal part of both linguals is given off from one side. In the latter case ligature of the small vessel on the other side would not prevent copious bleeding on that side. The blood may be prevented from entering the larynx (1) by the position of the head, hanging over the end of the table (Rose's position), in which the blood accumulates in the upper pharynx and escapes from the nose or mouth, which are now below the level of the larynx, or (2) by giving anesthesia through tubes passed through the nose into the lower pharynx and packing the oral pharynx.

The following *structures* are *divided* in an excision of the entire tongue: the mucous membrane connecting the tongue with the jaw, the epiglottis, and the soft palate; the genio-, hyo-, stylo-, and palatoglossi and the lingualis muscles; the lingual, hypoglossal, and glossopharyngeal nerves, and the lingual vessels and their anastomoses (see above). Excellent *drainage* may be provided through an opening beneath the jaw to guard against septic aspiration pneumonia, a not infrequent cause of death in such operations. **Wounds** of the tongue are not uncommon and may require suture. I have seen a case where a child bit her tongue half through, and a similar accident had occurred in two previous generations of the family.

As a consequence of the *vascularity* of the tongue it may be the seat of nevoid growths. The **lingual arteries** (averaging 3 mm. ($\frac{1}{8}$ in.) in caliber) pass upward and forward to the base of the tongue beneath the hyoglossus muscle, in front of which they run forward as the ranine arteries near the under surface of the tongue. They are often brittle, especially at the age when cancer is prevalent. *Cancer* tends to extend toward the best blood supply, hence lingual cancer tends to spread downward toward the root of the tongue, which is also the course of the lymphatics. The **lymphatics** of the tongue are numerous and important in connection with the nodular infection which occurs early in lingual cancer. Some of the lymphatics of the tip of the tongue enter the submental nodes, others pass to the deep cervical node just above the point where the omohyoid crosses the vessels. The lymphatics from the rest of the tongue pass mostly into the deep cervical nodes lying between the omohyoid and digastric muscles, especially into one just beneath the digastric, while a few from the border and lateral part of the dorsum pass into the anterior submaxillary nodes. The lymph from the network in the vicinity of the circumvallate papillæ may be carried to both sides of the neck, and infection may follow the same course and be bilateral. A few small nodes may lie along the course of the lymph vessels leading from the tongue to their several nodes. The enlargement of the tongue in the

strange congenital condition known as **macroglossia** is due principally to a great dilatation of the lymph channels (*lymphangioma*) and to an increase of the lymphoid tissue throughout the tongue. In some cases it reaches a prodigious size, filling and projecting far out of the mouth, and deforming the teeth and alveolar arches by pressing them forward. The base of the tongue is the part most affected. Excision by a wedge-shaped incision or the use of the cautery sometimes gives a good result.

Fig. 43



The lymphatics of the tongue; anterior view. (Poirier and Charpy.)

Nerves of the Tongue.—The **hypoglossal** supplies the *muscles* of the tongue, though the chorda tympani may carry some motor fibers from the facial. The **chorda tympani**, carrying fibers from the glossopharyngeal nucleus by way of the pars intermedia, supplies taste fibers to the anterior two-thirds of the tongue; the **glossopharyngeal** nerve supplies taste and sensory fibers to its posterior third. Branches of the *superior laryngeal nerve* supply sensation to the root of the tongue just

in front of the epiglottis. The **lingual** or gustatory nerve supplies sensation to the anterior two-thirds of the tongue, in which the *sense of touch* is more *acute* than in any other part of the body, and is used by dealers in precious stones when the eye alone cannot be trusted. This nerve is not infrequently affected by *neuralgia* or responsible for *reflex symptoms* in other branches of the fifth nerve, such as "earache," "toothache," trismus, etc., in painful affections of the tongue, which are most common in the anterior two-thirds of the organ. Neuralgia of this nerve in cancer of the tongue is sometimes so severe as to demand its *division or excision*. By pulling the tongue forward and to the opposite side the nerve may be made *prominent* by its elevating a *ridge* of mucous membrane on the floor of the mouth, between the tongue and the alveolar arch. The nerve may be excised after *dividing* the mucous membrane *along this ridge*, except in cases where the tongue is much enlarged and fixed by cancer, in which case it may be divided by a bistoury, entered a little over 12 mm. ($\frac{1}{2}$ in.) behind and below the last molar down to bone, cutting toward the tooth.

After the lingual nerve has passed forward from between the ramus and the internal pterygoid muscle it *runs beneath* the *mucous membrane*, 5 mm. ($\frac{1}{5}$ in.) from its reflection from the side of the tongue and then beneath the *sublingual gland*, with Wharton's duct. It can be readily *felt* by the finger pressed against the inner surface of the jaw in a direction downward and backward from the last molar tooth.

The part of the **floor of the mouth** between the tongue and the alveolar arch is covered by mucous membrane, reflected from the tongue to the gums, and is divided into two symmetrical halves by the frenum of the tongue. On either side of the latter is a well-marked *ridge*, directed backward and outward, due to the presence of the **sublingual gland.** Along each ridge the ten to twenty *ducts* of the gland open, and at the anterior ends of the ridge, on either side of the frenum, we notice the *papilla* on which is the *orifice of Wharton's duct*. The *duct of Bartholin*, from a group of lobes of the sublingual gland, opens with or near Wharton's duct.

Wharton's duct passes obliquely forward and inward for 5 cm. (2 in.) from the deep process of the submaxillary gland, near the posterior border of the mylohyoid. It *accompanies* the *lingual nerve, crossing above* the latter, which inclines inward to the tongue, and it lies beneath and behind, or internal to, the sublingual gland. Its walls are thin but *not distensible*, so that when it becomes *blocked* by an impacted calculus the *pain* from tension is intense, as it cannot become rapidly or largely dilated to form a cystic tumor.

Such a cystic tumor is known as a **ranula**, a term applied to cysts of varied origin filled with mucoid contents and situated under the tongue or in the floor of the mouth. Typical ranula is a *retention cyst* of the mucous glands; according to Recklinghausen most frequently of those that lie beneath the tip of the tongue. Other cysts in this situation are classed as ranula, including retention cysts of the sublingual gland ducts or of Wharton's duct.

The presence of *Fleischmann's sublingual bursa* is denied by most authorities, but according to Tillaux it is the seat of the acute or rapidly formed ranula, which sometimes occurs. Tillaux describes it as follows. It is triangular in form, situated between the genioglossus muscle and the mucous membrane which is reflected from beneath the front and sides of the tongue to the floor of the mouth. Its apex lies at the end of the frenum on the under surface of the tongue and its base at the sublingual gland, which separates the mucosa from the genioglossus muscle. It is constricted in its centre by the frenum and reaches back on either side to the first or second molar tooth. *Incision* alone will not cure a ranula, for after the incision heals the cyst refills. Its *lining membrane* must be *dissected out* as far as possible and the remainder cauterized.

Congenital dermoid or branchiogenic cysts in the floor of the mouth, between the tongue and the lower jaw, may resemble ranula. They are due to the imperfect closure of the first visceral cleft or arch. *Cysts or solid tumors* deeply seated in the tongue or in the vicinity of the hyoid bone may develop from the *thyroglossal duct,* leading from the foramen cecum. In this manner probably some of the deep-seated forms of cancer and cancerous cysts of the neck are formed.

The loose connective tissue in the floor of the mouth between the mylohyoid muscle and the mucous membrane, and secondarily that in the submaxillary region, is involved in the septic phlegmonous inflammation known as **Ludwig's angina.**

The Palate.—**The Hard Palate.**—The hard palate separates the mouth from the nose, so that when it is cleft these two cavities communicate. Its *form* is determined by that of the horseshoe-shaped alveolar arch which borders it. Normally the greatest *width* about equals its length, but this relation varies widely. Normally it presents a *flat arch,* abnormally a high and narrow one. The latter form is said to be common in congenital idiots and often occurs in the two halves of a cleft palate, especially in complete clefts. This is a fact of importance in the closure of the cleft, for in such cases the flaps, when brought down to a more horizontal position, are ample to meet and be sutured in the median line. These *flaps* consist of the entire soft parts which cover the bone and are composed of a firm pale mucosa fused with the periosteum so that they cannot be separated. This dense, tough *mucoperiosteum* is thickened by the many *glands* which are contained between its two layers, except in the median line. Posterior to the anterior palatine foramen a median raphé indicates the formation of the palate from two lateral halves.

The mucoperiosteum is supplied principally by the **posterior palatine artery,** which lies near its deep surface and passes forward, close to the junction of the palate and the alveolar process, from the lower opening of the posterior palatine canal, internal to the last molar tooth and about 8 mm. ($\frac{1}{3}$ in.) in front of the hamular process. The two *principal dangers* of operations for the closure of a cleft of the hard palate are *hemorrhage and gangrene* of the flaps, both due to a division of the posterior palatine artery or its branches which pass inward to supply the mucoperiosteum. Hence this division should be avoided, and the *artery* and its branches

preserved in the flap for its nourishment, by making the *lateral incision*, bordering the flap, along the base of the alveolar process, outside the course of the artery. The *nerves* come from Meckel's ganglion.

The Soft Palate.—The soft palate is of about the same *length* as the hard palate, but it is *broader* than it is long, and about 6 mm. ($\frac{1}{4}$ in.) thick. Its *sides* are merged into the pharyngeal wall. The **anterior third** of the soft palate contains the **palate aponeurosis**, which is always *firm and tense*, so that, as it is continuous in position and direction with the hard palate, it is not easy to distinguish it from the latter by the touch, as in passing a Eustachian catheter (see p. 64). The aponeurotic portion does not share in the movements of the posterior or muscular portion of the soft palate. The *tendon* of the *tensor palati* muscle is connected with this aponeurosis, which is already tense and can scarcely be made much more so. Indeed, it is probable that the *principal action* of this muscle, certainly of those fibers attached to the fibrous portion of the Eustachian tube, is to open that tube. Such an opening occurs whenever the palate is raised, as in swallowing, and on this fact depends the Politzer method of inflating the middle ear (see p. 64).

The fibers of the *palatoglossus* form the most inferior layer of those which make up the substance of the soft palate. All the muscles of the palate join those of the opposite side in the median line, and hence, with the exception of the azygos uvulæ, by their *contraction* tend to *widen a cleft* of the palate or *pull it apart when sutured*. According to some the levator and tensor palati are the chief agents drawing asunder the sutured cleft. To *prevent this* interference with the success of the operation many have employed free anteroposterior *incisions* through the palate along the side of each half, to divide the muscles, or a *tenotomy* of one or more muscles, especially the levator palati and palatopharyngeus. Billroth *broke off* the *hamular process* and displaced it inward, together with the tensor palati tendon which winds around it, in order to relax the latter, with good results. The hamular process can be felt to the inner side and behind the last upper molar tooth. Others use various forms of tension sutures and plates. Wolff thinks the soft palate is best relaxed by separating the mucoperiosteum from the bony hard palate, as in operations to close clefts of the latter. In any case the aponeurosis must be freed from its attachment to the posterior border of the bony palate, to allow the anterior part of the soft palate to come together readily.

The **posterior two-thirds** of the soft palate, the portion behind its aponeurosis, forms the **velum pendulum palati** proper, or the movable curtain which in breathing through the nose hangs down in the isthmus of the fauces and shuts off the mouth from the pharynx, and in deglutition or breathing through the mouth is raised to a horizontal position to shut off the buccal portion of the pharynx from the nasopharynx, to prevent food entering the latter in swallowing. Hence in *paralysis* of the palate, as sometimes occurs after diphtheria and from other causes, the palate cannot be raised, the nasopharynx is not shut off, and fluids are liable to regurgitate through the nose. The *elevation* of the palate during breath-

ing through the mouth is taken advantage of in one form of nasal irrigation (see p. 87). When the palate is elevated it is enabled to shut off the buccal from the nasal portion of the pharynx by the contraction of the *superior constrictor muscle* which narrows this part of the pharynx and brings forward its posterior wall.

The azygos uvulæ passes into the **uvula** and by its contraction shortens and raises it. *Elongation* of the uvula is largely due to hypertrophy of the part near the tip, beyond the muscle. When elongated it may touch the base of the tongue or produce coughing in the supine position by irritating the back wall of the pharynx. It may be readily snipped off if necessary. From the base of the uvula two folds of mucous membrane pass off on either side in an outward and downward direction, the *anterior and posterior pillars of the fauces.* The **anterior folds** cover the palatoglossi and incline somewhat forward. The **posterior folds** cover the palatopharyngei and incline somewhat backward. As the latter approach nearer to one another than the anterior pillars, they are readily seen behind them. Between the two pillars of each side lie the tonsils (see p. 124). The space between them forms the **isthmus of the fauces,** the opening between the mouth and the pharynx, which is *bounded* by the tongue below and by the palate above. In deglutition, after the food is passed into the pharynx, the isthmus is closed by the contraction and approximation of its pillars and the elevation of the back of the tongue to the palate, to shut off the mouth from the pharynx.

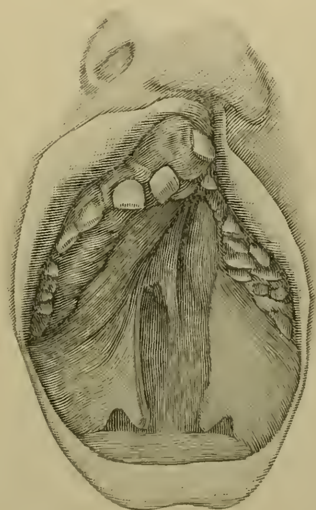
The **blood supply** of the soft palate is derived from the ascending palatine branch of the facial, the palatine branch of the ascending pharyngeal artery, and the descending palatine branch of the internal maxillary. The **lymphatics** of the lower surface of the palate enter the deep cervical nodes along the jugular vein just beneath the digastric. Some of those of the upper surface enter the retropharyngeal nodes. The **sensory nerves** come from Meckel's ganglion and the glossopharyngeal. The latter nerve probably supplies the scattered taste buds found on the under surface of the palate. The terms palatable, to tickle the palate, etc., are not without physiological foundation in fact, though the tongue is the principal organ of taste.

Development (see also p. 111).—The palate is formed by the junction in the middle line of the palatal plates of the maxillary processes which grow backward and inward to separate the mouth from the nose. This union begins in front about the eighth week of fetal life and is completed posteriorly in the ninth and tenth weeks. Throughout the hard palate this line of union is joined from above by the frontonasal process, forming the septum of the nose, to the lower and anterior angle of which are attached the premaxillary bones. These bones join the palate processes of the maxillæ along suture lines passing forward and outward from the anterior palatine foramen to the interspace between the canine and lateral incisors of each side, so that they contain the four incisor teeth.

Congenital cleft palate is an error of development, a failure of fusion of the parts of which the palate is formed. In the *soft palate* the *cleft* is *median* and *single;* in the *hard palate,* as far forward as the anterior

palatine foramen, it is nearly or quite median in position, but is called *unilateral* or *bilateral* according as one or both palatal processes fail to join the vomer. If the cleft is unilateral, it communicates with the nasal fossa of one side; if bilateral, with both nasal fossæ, and the free border of the vomer appears in or above the cleft. In one case I observed entire absence of the nasal septum, which occurs occasionally. *In front of the anterior palatine foramen* the *cleft*, in extending through the alveolar border, is always unilateral or bilateral, *never median*. If the cleft is bilateral, the *premaxillary bones* are entirely separate from the maxillæ, and, supported on the end of the nasal septum, they often protrude forward and appear to be suspended from the end of or beneath the nose. Such bilateral clefts are usually associated with a double harelip, a unilateral cleft with a single harelip. In unilateral clefts the alveolar process of the premaxillary bones may be on a line with the alveolar process across the cleft, or it may project in front of it.

Fig. 44



Left-sided harelip and cleft palate. Marked displacement of intermaxillary bone. Boy, aged six years.

According to Kölliker and others, the cleft in the lip and alveolar process is between the frontonasal and the maxillary process, *i. e.*, between the premaxillary bones and the maxilla or between the lateral incisor and canine teeth. But Albrecht regards it as between the frontonasal and the lateral nasal processes, assuming four premaxillary bones, two on either side, and claiming that the cleft is between the central and lateral incisors. Both views are probably correct, and the position of the clefts is not always constant; some are between the lateral incisor and canine teeth, others between the lateral and central incisors, but more often the lateral incisor is wanting. The protruded premaxillary bones in bilateral clefts contain, as a rule, the germs of the central incisors only.

Cleft palate *varies greatly* in *extent*. Rarely it may involve the uvula only or merely the middle of the soft palate. A cleft of the soft palate often exists without any in the hard palate, or at most only in the posterior part of it; but clefts of the hard palate rarely occur without one in the soft palate. In rare cases the premaxillary bones may be entirely absent, and the co-existing double harelip shows a large median gap.

The **usual operation** consists in *broadly freshening* both edges, dissecting up a *flap of mucoperiosteum* on each side as far as the alveolar process, where it is limited by an incision along the base of the process (p. 120), and then bringing together and *suturing the edges*. In infants under

three months, and possibly up to six months, the cleft may be closed by Brophy's method, forcibly pressing the two maxillæ together and holding them by two transverse wires passed through and fastened over lead plates on the outer surfaces of the alveolar processes. It seems better to treat some bad clefts of the palate by an *obturator* fastened to the six-year molars. Such obturators, if well made, give an excellent functional result as far as speech and swallowing are concerned. Infants with cleft palate can usually nurse from a bottle if a large nipple is used which fills up the cleft. But later on articulation is very imperfect and the voice very nasal in tone.

The Tonsils.—The tonsils are masses of lymphoid tissue covered with mucous membrane and situated in the *triangular recesses* between the pillars of the fauces and the base of the tongue. The *floor* of this recess is formed by the pharyngeal aponeurosis and the superior constrictor muscle, on which each tonsil rests and by which it is separated from the **pharyngomaxillary space.** The *latter lies* between the lateral wall of the pharynx internally, the internal pterygoid muscle externally, and the upper cervical vertebræ posteriorly, and contains fat and loose cellular tissue. Zuckerkandl showed that it was *divided* by the styloglossus and stylopharyngeus muscles into an *anterior chamber,* contiguous to the tonsil, and a *posterior chamber* containing in its hindermost part the internal carotid artery the internal jugular vein and their accompanying nerves (Fig. 46).

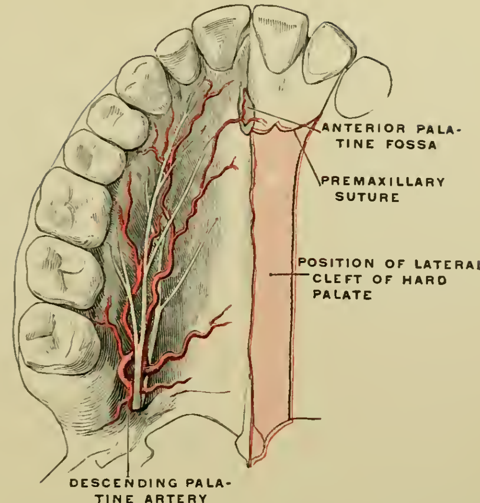
Quinsy, which is a *peritonsillitis,* or an inflammation around the tonsil, is confined in most cases to the *anterior chamber* of this space, and only rarely extends to the posterior chamber, in which case the internal carotid might possibly become eroded, as reported in a few cases. The peritonsillar inflammation in the anterior chamber meets no obstacle in extending outward as far as the internal pterygoid muscle, but then further swelling projects inward toward the mouth in the line of least resistance.

A quinsy is *usually opened* through the soft palate just above the tonsil by an incision parallel with the anterior faucial pillar. **Wounding the internal carotid** is out of the question, for in the *adult* it lies 3 cm. ($1\frac{1}{4}$ in.) behind this point in the normal state and probably twice as far when the parts are bulged forward by the inflammation. In *children* the distance is relatively even greater, though, of course, actually somewhat less. As the internal carotid is about 2 cm. ($\frac{4}{5}$ in.) behind the tonsil, there is even less danger of its being wounded in *tonsillotomy,* for no puncture is then made. A wound of the artery has probably never occurred from tonsillotomy or opening a peritonsillar abscess, though several cases are recorded where the artery has become eroded in a peritonsillar inflammation. It is in operations on the lateral aspect of the pharynx that the internal carotid is in danger of being wounded.

The **external carotid artery,** 2 cm. ($\frac{4}{5}$ in.) from the lateral periphery of the tonsil, though equally near, is still more out of the way, lying external to the muscles arising from the styloid process. The *ascending pharyngeal artery* is nearer the tonsil than the internal carotid, and gives a branch

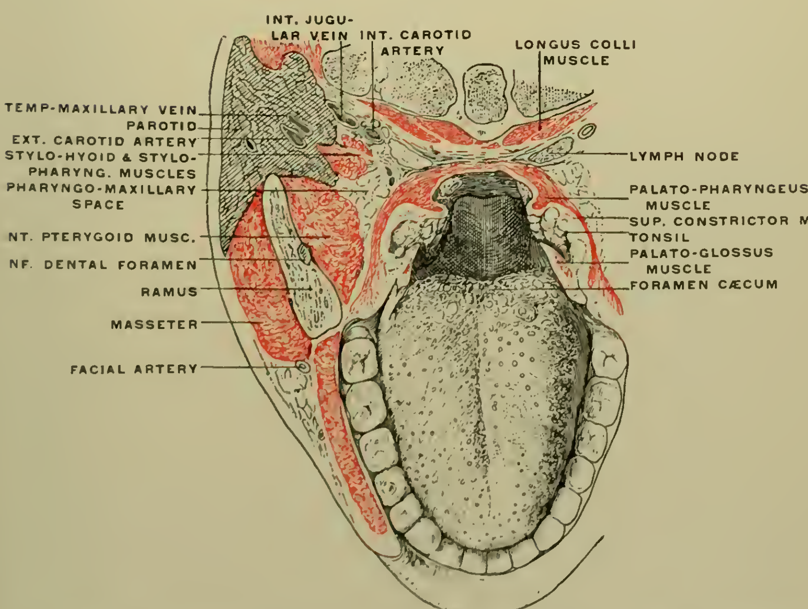
PLATE V

FIG. 45



Hard Palate, showing the course of the arteries and of a lateral cleft. (Modified from Merkel.)

FIG. 46



Horizontal Section through the Commissure of the Lips and the Tonsils. (Merkel.)

The section passes through the odontoid process, and shows the pharyngomaxillary space.

to it, but lies behind it in the pharyngomaxillary space, and its main trunk is not exposed to injury in tonsillotomy. In one of the very few cases where fatal bleeding followed this operation the *tonsillar branch of the facial* was proved to be the source of hemorrhage. *Bleeding* from *the ascending pharyngeal* artery has proved fatal in a case reported by Mr. Morrant Baker, but it did not follow tonsillotomy, but a wound due to a pipestem driven through the tonsil. According to Merkel, the *source* of *severe arterial hemorrhage* after tonsillotomy, etc., is in most cases the *facial* artery, which, as it passes between the digastric and styloglossus muscles, may take a sharp S-shaped bend, which comes very close to the lateral surface of the tonsil. As the tonsil is separated from the floor of its recess by loose cellular tissue it can be drawn out of this recess, still farther from the vessels, for the purpose of its removal.

The **position** of the tonsil corresponds superficially to a point a little above and in front of the angle of the jaw, but, owing to the intervening structures, enlargement of the tonsil other than malignant cannot be felt externally. What is felt and mistaken for the tonsil is an enlargement of the lymph nodes here which regularly accompany affections of the tonsil. Enlarged or *hypertrophied tonsils project* in the line of least resistance toward the median line, where they may even meet and cause difficulty in swallowing. As the projecting mass of hypertrophied tonsils also narrows the pharyngeal passageway between the nose and the larynx, the subject of such hypertrophy sleeps with the mouth open, to get more air, and usually snores.

In the inflammation known as *follicular tonsillitis* the openings of the twelve or fifteen *crypts* on the free internal surface of the tonsil are filled with a yellowish-white deposit composed of desquamated epithelium, leukocytes, bacteria, etc. The decomposition of retained epithelial structures and food debris within the crypts of an enlarged tonsil may give rise to foul breath and to the repeated attacks of inflammation to which such tonsils are liable. The attachment of the tonsil to the muscles of the pharynx renders *deglutition painful* in acute inflammations of the tonsil, because of the movements conveyed to the latter by the movements of the pharynx. Thus the superior constrictor moves it inward and the stylopharyngeus outward. The action of the latter in drawing the tonsil outward, combined with a prominent anterior faucial pillar, may make it difficult to reach the tonsil with the *tonsillotome*. The latter should be introduced backward and slightly downward, for this is the direction of the *long axis* of the tonsil, which normally measures about 2.5 cm. (1 in.). Its postero-inferior end is sometimes hard to inspect.

Although the *blood supply* is from multiple sources, the uninflamed tonsil is not very vascular, so that it often bleeds but little on removal, but if removed when inflamed it may give rise to troublesome hemorrhage, which may be controlled by pressure outward against the jaw. The **arterial supply** comes from the tonsillar branch of the facial, the descending palatine branch of the internal maxillary, the dorsalis linguæ branch of the lingual and branches of the ascending pharyngeal. The **lymphatics** of the tonsil enter the deep cervical nodes beneath the posterior

belly of the digastric. These are situated near the angle of the jaw, and may be readily felt when enlarged. The *nerves* come from Meckel's ganglion and the glossopharyngeal nerve. The latter as it winds around the palatopharyngeus is in such close relation to the tonsil as to be in some danger of injury in operations on or about the tonsil.

The tonsil is not infrequently the seat of *malignant newgrowths*, sarcoma and epithelioma, on account of which it is removed with a wide margin of healthy tissue, either through the mouth, after splitting the cheek or dividing the jaw, or through the neck by a lateral pharyngotomy.

The Pharynx.—The pharynx *extends* from the basilar process of the occipital bone to the lower part of the cricoid cartilage, which is opposite the sixth cervical vertebra when the neck is neither flexed nor extended. It is 11 cm. ($4\frac{1}{2}$ in.) *long*, much *wider* transversely than anteroposteriorly, widest, about 4.5 cm. ($1\frac{3}{4}$ in.), between the fossæ of Rosenmüller, and *narrowest*, 14 mm. ($\frac{3}{5}$ in.), at the *lower end* where it is continuous with the esophagus. Hence **foreign bodies** which reach the pharynx are most likely to be arrested at the latter point, which is a little beyond the reach of the finger, for it measures 15 cm. (6 in.) *from the incisor teeth.* The latter measurement should be remembered in passing esophageal bougies to determine the position of a stricture, and it should be added to the length of the esophagus, 23.5 cm. ($9\frac{1}{2}$ in.), to determine the distance from the teeth to the stomach.

The variety of foreign bodies reported as arrested in the pharynx is very great. Perhaps the most common are large masses of food swallowed gluttonously, a frequent occurrence among the insane. When the foreign body is a large one it may block the laryngeal opening and thereby cause suffocation. As *corrosive fluids* pass the narrowest point more slowly than the wider parts, the corrosive action is more intense and the resulting cicatricial contraction more marked at the lower end of the pharynx than they are above.

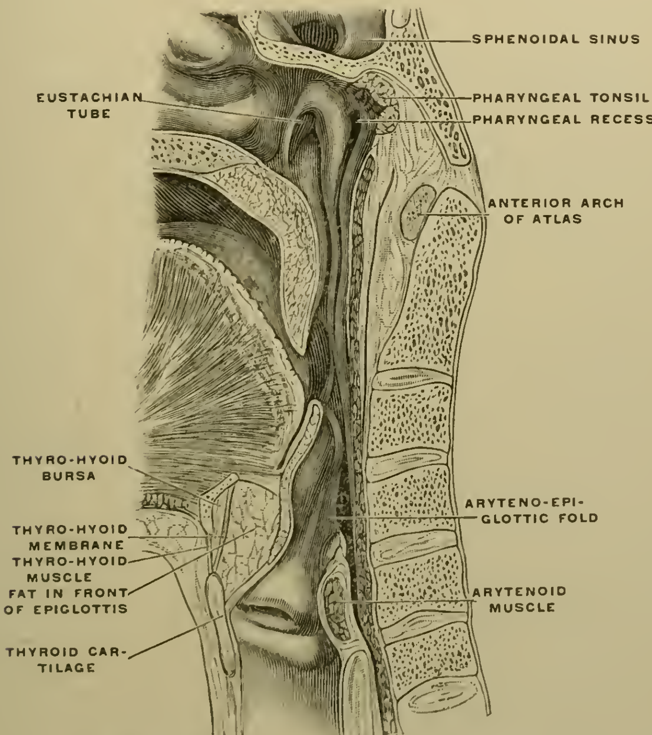
The pharynx is *complete behind* and at the sides, where its musculo-membranous walls separate it from the surrounding parts. It is *incomplete in front*, where it presents the *openings* of the posterior nares above, the faucial opening into the mouth below, and still lower the upper orifice of the larynx. The *front* of the pharynx is held *open* by its attachment to the following fixed points, the internal pterygoid plate, mandible, hyoid bone, and thyroid and cricoid cartilages.

Relations of the Pharynx.—**The posterior wall** of the pharynx is in front of the bodies of the upper five *cervical vertebræ.* The anterior arch of the *atlas* is on a *level with the palate*, and behind the mouth one can palpate the anterior surface of the bodies of the second and third cervical vertebræ, and so determine the existence of a *fracture, dislocation, or disease* of these vertebræ. Owing to their distance from the incisor teeth it is difficult to satisfactorily palpate the fourth and fifth cervical vertebræ. Necrosed portions of the upper cervical vertebræ have been discharged through the mouth.

In caries of the upper cervical vertebræ, which is most common in children, a **retropharyngeal abscess** may form in the loose tissue sepa-

rating the posterior pharyngeal wall from the prevertebral fascia. One or two *lymph nodes* on either side situated in this loose tissue opposite the lateral masses of the atlas receive lymph vessels from the nasal fossæ, the nasopharynx, the Eustachian tubes, etc., and may also be the starting point of such an abscess. These abscesses may push forward the posterior pharyngeal wall so as to depress the soft palate, or, if they extend farther downward, they may cause dyspnea by obstructing the opening into the larynx. Though they may open or be *opened* through the mouth, it is preferable to open them by an incision along the sterno-

Fig. 47



Sagittal section of the pharynx, etc. (Zuckerkandl.)

mastoid, either in front or behind, after passing behind the great vessels and the parotid gland. This is especially true in tuberculous abscesses, to avoid mixed infection. If they discharge spontaneously into the pharynx during sleep, the pus may be inspired and cause suffocation or set up septic pneumonia. Abscess in this *loose retropharyngeal tissue* may descend along the esophagus into the posterior mediastinum, even to the diaphragm. This loose tissue serves the purpose of a serous cavity and allows the free movements of the pharynx.

The **lateral walls** of the pharynx are in *close relation* with the *internal carotid* arteries and their accompanying nerves (ninth, tenth, and eleventh

and sympathetic nerves) (see Fig. 46), so that the pulsations of the artery may be felt through the pharyngeal wall and the artery may be wounded by foreign bodies thrust through the wall. The internal jugular vein is less exposed to injury from such causes, as it is more laterally placed. The *styloid process* and its muscles, the inner end of the *parotid gland,* and the upper end of the *thyroid gland* are also in relation with the lateral walls of the pharynx. If *epithelioma* involves a part of the pharynx, as occasionally happens, with or without invasion of the tonsil, it may be *reached* through an *incision* on the side of the neck. In such cases the external carotid is tied, and, in order to reach the upper end of the pharynx, a division or temporary resection of the jaw may be made. The *lower end* of the pharynx may also be *reached by subhyoid pharyngotomy* through the thyrohyoid membrane, an operation which also exposes the portion of the larynx above the glottis.

The Nasopharynx.—The nasopharynx, or the upper part of the pharynx which is above the level of the palate and behind the posterior nares, is entirely *respiratory* in function. Accordingly its epithelium is *ciliated,* and it is shut off from the lower or buccal portion, during the act of swallowing, by the elevation of the soft palate. The *superior constrictor* does not reach to its upper end at the sides, as the constriction of this part serves no purpose. In Politzer's method of inflating the middle ear the nasopharynx is shut off from the parts below by the act of swallowing, in which the palate is raised, so that the air forced into the nose finds no exit except through the Eustachian tube.

The nasopharynx is very rich in lymphoid or *adenoid tissue,* and a mass extending around its posterior wall between the orifices of the Eustachian tubes is known as the **pharyngeal or Luschka's tonsil,** which is often hypertrophied. Such hypertrophy is frequent, and may reduce Rosenmüller's fossa to a narrow fissure. Reaching from this point forward, the mucosa of the roof and upper part of the pharynx is rich in similar tissue which, when hypertrophied, gives rise to **nasopharyngeal adenoids.** The latter obstruct the posterior nares; compress and obstruct the openings of the Eustachian tubes; are a common cause of deafness and otitis media; cause mouth breathing, snoring, frequent colds, running of the nose, lack of development of the nose and the body of the maxillæ, resulting in a high arch of the palate; affect the voice; and are often associated with mental apathy and dulness. After puberty they tend to diminish and the nasopharynx also becomes more capacious; but before this time they should be removed, if well-marked, to avoid the many evil consequences.

The **roof and posterior wall** of the nasopharynx is formed by the obliquely sloped under surface of the body of the sphenoid and of the *basilar process* of the occipital bone and the thick layer of ligaments and fibrous tissue which fills in the angle between the latter and the vertebræ. From this fibrous tissue, or the periosteum, spring the **nasopharyngeal polypi,** which may be pedunculated or sessile, benign or sarcomatous, and which occur most often in male children. Even when benign they may by their growth fill up the nasopharynx, depress the soft palate, become *prolonged* into the nasal fossæ, the maxillary sinuses, and even through the

sphenopalatine foramen, and they may possibly erode the base of the skull. Their *removal* if pedunculated may be secured by a wire snare or galvanocautery loop introduced through the nose, through a temporary resection of the maxilla, a division of the palate, and in many other ways. After about twenty years of age they grow much less rapidly or not at all, and are even said to atrophy, hence the removal of a small one at this time may be unnecessary so far as its mechanical obstruction is concerned.

The *lower part of the pharynx* is *funnel-shaped*, narrowing to its narrowest point at its lower end. All below the nasopharynx is lined by stratified epithelium. Both the stylo- and palatopharyngei elevate the pharynx, the former also widens it, and the latter narrows very strongly the isthmus of the fauces and helps to shut off the mouth from the pharynx in the second act of deglutition.

The **lymphatics** of the pharynx pass to the upper deep cervical nodes, whose enlargement may depend upon an inflammation or some other affection of the pharynx. The lymphatics of the upper part of the pharynx first pass through the postpharyngeal node.

THE NECK.

The neck or the *passageway* between the head and the thorax is subject to wide *variations* as to its *length, size,* and *shape.* The abundance or lack of adipose tissue is largely responsible for the increase or decrease of size and for the rounded or angular shape. In extension of the neck its anterior part is lengthened and in flexion is shortened, so that the distance of its movable parts from the sternum or the lower jaw varies, as does also the relation of these parts to the vertebræ. Hence in giving the relative position of its landmarks, the neck is supposed to be in the position midway between flexion and extension, *i. e.*, the natural upright position, unless otherwise stated.

Landmarks and Surface Markings.—**Anterior Median Region.**—In the angle between the chin and the neck the **hyoid bone** and its great cornua can be made out. The *body* of the bone is on a level with the fourth cervical vertebra and nearly on a level with the angles of the jaw. The upper borders of the *cornua* are guides to the lingual arteries which run just above them. Below the hyoid bone is the **thyrohyoid membrane,** which corresponds posteriorly with the epiglottis and the upper aperture of the larynx. This membrane is limited inferiorly, one finger's breadth below the hyoid, by the **thyroid cartilage,** whose upper border corresponds to the bifurcation of the common carotid. The parts of the thyroid cartilage and the **cricothyroid space,** between it and the cricoid cartilage below, can be readily made out. The projection of the *thyroid angle* (pomum Adami) is much more prominent in males after puberty, but the **cricoid** is always to be made out about 3 cm. (1¼ in.) below its upper end. It *corresponds to* the upper end of the *sixth cervical vertebra,* to the junction of the pharynx and esophagus and of the larynx and trachea, and to the crossing

of the common carotid by the omohyoid muscle. Below the cricoid the **trachea** may be felt, but its individual rings cannot be distinguished. As it descends it becomes less easily felt, for it is covered more deeply by the lower thicker part of the neck, so that at the *episternal notch,* on a level with the disk between the second and third thoracic vertebræ, it lies nearly 3.5 cm. ($1\frac{1}{2}$ in.) from the surface.

The *thyroid gland* cannot be distinctly felt unless enlarged. On deep pressure *opposite the cricoid cartilage,* over the line of the carotid artery, the prominent anterior tubercle of the sixth cervical vertebra can be felt, and the artery can be compressed against it, as advised by Chassaignac. Hence it is called the *carotid tubercle* or Chassaignac's tubercle. As the omohyoid crosses the carotid at this point, the latter is more superficial and more easily compressed just above it. The vertebral artery may be controlled by pressure below it.

In the **median line at the back of the neck** there is a slight *depression* between the prominences which are due to the trapezius and complexus muscles on either side. At the upper end of this depression is the **occipital protuberance,** about 5 cm. (2 in.) below this the *spine of the axis* can be felt on deep pressure, and below this the spines of the third, fourth, and fifth vertebræ can be felt as a bony ridge, but not commonly as individual spines. The spine of the **vertebra prominens** (seventh cervical) can be very plainly felt, and represents the lower limit of the neck. The spine of the first dorsal is still more prominent. In most cases the sixth spine can be distinctly felt and sometimes it may be even mistaken for the seventh spine. The sixth cervical is commonly the last bifid spine.

At the side of the neck the *transverse process* of the *atlas* may be felt just below and in front of the tip of the mastoid process, and in the upper part of the supraclavicular fossa the *transverse process* of the *seventh cervical vertebra* can be felt on deep pressure. The angle between the submental region and the neck corresponds about to the hyoid bone and is continued as a groove and a crease in the skin backward and upward beneath the angle of the jaw to the *subauricular depression* in front of the mastoid, behind the jaw and below the ear. In very fat subjects it may not be present. The groove corresponds to the line of Kocher's incision for the upper cervical triangle.

The sternomastoid muscle is altogether the most important landmark of the neck. It is prominent in thin subjects and when thrown into action. Its **anterior border** is the thicker and better marked, and along it runs a communicating branch from the facial to the anterior jugular vein in the lower part of the neck. Extending from the tip of the mastoid to a point just internal to the sternoclavicular joint, this border *overlies the common carotid,* the pulsation of which can be felt on slight pressure, and is the *guide for many incisions.* The **sheath** of the muscle, which is derived from the superficial layer of the deep cervical fascia, is thicker near the middle of the muscle than below or above. The *triangular interval between the sternal and clavicular heads* of the muscle is very evident in thin subjects as a slight depression. Beneath the lower end of this interval, *i. e.,* just above the sternoclavicular joint, lies the

common carotid on the left and the bifurcation of the innominate artery on the right side, and on both sides the margin of the pleura and lungs at a deeper level.

The **action** of the sternomastoid of one side is to flex the head forward and laterally, to the side of the muscle, and rotate it to the opposite side. The fibers of the sternal fasciculus cross superficial to those of the clavicular portion so as to be inserted behind them above. The *clavicular portion* produces the lateral flexion, the *sternal portion* the rotation. This difference of action is important, and is illustrated in **torticollis or wryneck,** a condition often congenital, sometimes acquired, and due to a *contracture* or *spasmodic contraction* of one muscle or the paralysis of the opposite one.

The **congenital cases** are *due* most often to an injury at birth, too great traction on the after-coming head, or the pressure of the forceps. A hematoma forms within the sheath of the ruptured or injured muscle and the injured part is replaced by fibrous tissue, or the pressure of the extravasation causes an ischemic degeneration and contracture. According to some the latter may occur from pressure in utero. The deformity may not be noticed for some time after birth and increases with the cicatricial contraction of the injured muscle and cervical fascia and with the diminished growth of the muscle. In this form of wryneck the **treatment** is *division of the muscle.* This was formerly practised *subcutaneously* 2 cm. ($\frac{3}{4}$ in.) above its lower end in adults, 1 cm. above in children, so as to avoid the anterior jugular vein which passes beneath the lower end of the muscle to join the external jugular, which lies along its posterior border. The latter vein is generally out of danger, as *only the sternal portion* of the muscle is usually *divided,* for it is the rotation due to this portion which is particularly characteristic of torticollis. The great vessels are not in danger, as they are here overlapped by the sternohyoid and sternothyroid muscles. The *open division* is far *preferable,* as everything can be divided that prevents the correction of the deformity, including the contracted sheath and the cervical fascia. It should be done before secondary changes in the vertebræ and soft parts have taken place.

Spastic wryneck may be due to a reflex irritation. The *spinal accessory nerve,* together with a few fibers of the second and third *cervical nerves,* supplies the muscle. In such forms of wryneck the *spinal accessory* is often *excised* and may be *exposed* where it reaches the anterior border of the muscle, 2.5 to 3.5 cm. (1 to $1\frac{1}{2}$ in.) below the tip of the mastoid. This nerve traverses the muscle about the junction of its upper and middle thirds, emerges at the posterior border a little above its middle, crosses the posterior triangle obliquely and passes under the trapezius on a level with the seventh cervical spine. It supplies the latter in conjunction with the third and fourth cervical nerves. In some *severe cases* of spastic wryneck the trapezius and other muscles at the back of the neck are involved, and besides the spinal accessory the posterior primary divisions of the upper three or four cervical nerves may require resection. The spinal accessory may be divided in operations on

the neck, especially in operations for enlarged glands. The effect of this is variable. In some cases the sternomastoid muscle is paralyzed and atrophied, in others it is not. This difference is explained by the fact that the nerve supply furnished by the cervical nerves is sometimes very slight, and that it sometimes reaches the muscle throughout the spinal accessory in other cases separately. The trapezius is less often affected. The spinal accessory is sometimes used for anastomosis with the facial nerve in persistent paralysis of the latter.

Besides forming a *guide for the incision in many operations,* the sternomastoid *divides the anterolateral region* of the neck, in front of the trapezius muscle, into *two triangles.* These **primary surgical triangles** are *subdivided* into several *smaller surgical triangles* by muscles which are also of service as *landmarks* in operations on the neck. These triangles bounded by and containing landmarks are of practical use, for their contents can be located with reference to these boundaries and landmarks.

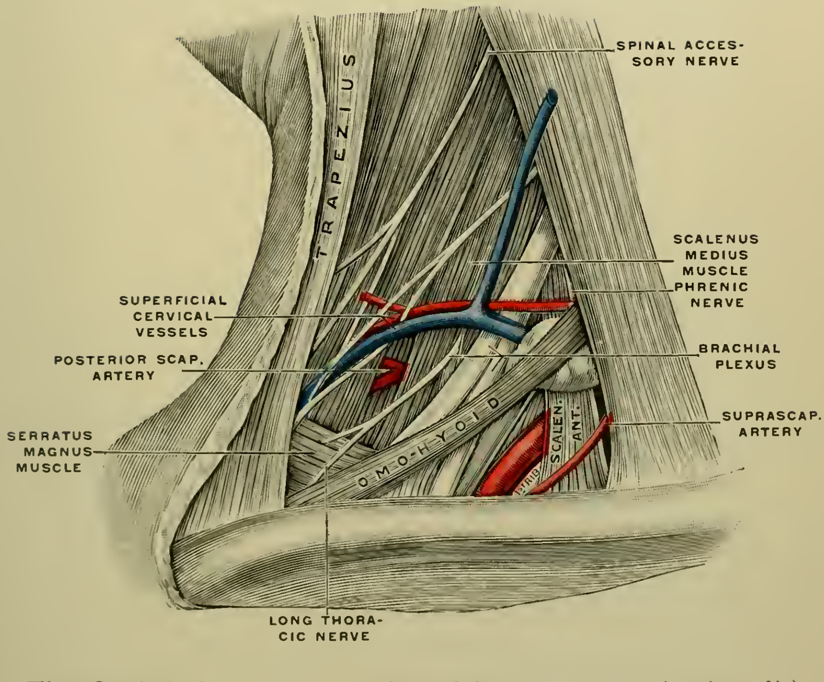
The posterior triangle (Fig. 48) is *subdivided* by the posterior belly of the *omohyoid* into an inferior or subclavian and a superior or occipital triangle. The **occipital triangle,** *bounded* by the sternomastoid in front, the trapezius behind, and the omohyoid below, **contains** comparatively little of practical importance. The *superficial cervical nerves* appear at the posterior border of the sternomastoid. The small occipital, great auricular, and transverse cervical nerves emerge just above the centre of the muscle, the first running up to the scalp near the posterior border of the muscle, the second across the muscle to the back of the ear, the third straight forward across the muscle. Lines drawn from the middle of the posterior border of the muscle to the sternum, the middle of the clavicle, and the acromion represent the course of the suprasternal, supraclavicular, and supra-acromial nerves. The *spinal accessory nerve* crosses this triangle as described above.

The subclavian triangle (Fig. 48) about corresponds to the wide depression above the clavicle, the **supraclavicular fossa,** which is well-marked except in stout subjects and infants. In some *fractures of the clavicle* this fossa may be *obliterated* or even replaced by a prominence. This triangle is **bounded** below by the clavicle, above by the posterior belly of the omohyoid, and in front by the posterior border of the sternomastoid. The **posterior belly of the omohyoid** can be made out in thin necks and especially when in action. It runs along a little above the clavicle, inclining somewhat upward as it passes forward to pass beneath the *sternomastoid,* about 2.5 cm. (1 in.) above the clavicle. The *posterior border* of the latter can be made out when in action. The attachment of its *clavicular portion varies in width,* and in some cases, especially in muscular subjects, it encroaches on the subclavian triangle so as to require division in operations in this region.

At a deeper level the posterior border of the **scalenus anterior muscle** roughly corresponds to that of the sternomastoid, though it has a somewhat different direction. Hence we may say that there are two triangles of which the deeper is bounded in front by the scalenus anterior. It is more readily felt and a better landmark than the scalene tubercle. The

PLATE VI

FIG. 48



The Occipital and Subclavian Triangles. (Zuckerkandl.)

The head is turned away to the left and the clavicle is strongly depressed. The posterior scapular artery is unusually deep and has separated unusually early from the superficial cervical artery.

phrenic nerve lies in front of this muscle and crosses it obliquely, being directed toward the lower end of its inner border, where it passes behind the subclavian vein. It has been known to pass over the third portion of the subclavian (Agnew). This nerve *commences* at about the level of the hyoid bone, and is *formed by* branches from the third and fourth cervical. It lies deeply and descends underneath the sternomastoid, being about midway between its two borders at the level of the cricoid cartilage.

Crossing the outer surface of the sternomastoid and the subclavian triangle in a line from the angle of the jaw to the centre of the clavicle is the **external jugular vein.** It crosses the sternomastoid obliquely to reach its posterior border, the lower third of which it follows. The lower dilated end or "*sinus*" of the vein, between a point 3.5 cm. ($1\frac{1}{2}$ in.) above the clavicle, where it pierces and is adherent to the deep cervical fascia, and its entrance into the subclavian vein in front of the scalenus anterior, *receives* the transverse cervical and suprascapular veins. These veins sometimes present a plexiform arrangement in the subclavian triangle, and may render more difficult the operations in this triangle. Owing to its adherence to the deep cervical fascia the "sinus" of this vein *remains patent* and is liable to *admit air* when it is opened.

At the floor of the triangle **the subclavian artery** describes a *curve* from the sternoclavicular joint to the centre of the clavicle, the highest point of the curve rising 12 to 25 mm. ($\frac{1}{2}$ to 1 in.) above that bone. On the *left side* the artery lies more deeply and does not rise so high in the neck as on the right side. At the outer border of the sternomastoid and just above the clavicle the *pulsation* of the artery may be felt, and here it may be *compressed* against the first rib by pressure downward and backward when the arm is drawn downward. Normally the artery does not rest directly upon the rib, but is slung, as it were, 6 mm. ($\frac{1}{4}$ in.) or more above it, between the scaleni anterior and medius.

The artery may be **ligated** in its third portion, which lies in this triangle external to the scalenus anterior, by an **incision** about 10 cm. (4 in.) long a finger's breadth above the clavicle. The **layers divided** in reaching the artery are the following: (1) skin; (2) scanty subcutaneous connective tissue; (3) platysma; (4) second connective-tissue layer with fat; (5) superficial layer of deep cervical fascia from the sheaths of the sternomastoid and trapezius; (6) third layer of loose connective tissue; (7) middle layer of deep cervical fascia, forming the sheath of the omohyoid and connected with the subclavian vein; (8) fourth layer of connective tissue in which lie the lymph nodes, the end of the external jugular vein, the subclavian artery and vein and their branches, and the brachial plexus, etc. The *external jugular vein* (see above) should be *cut* between two ligatures, as should also the suprascapular vein. The *suprascapular* and *transverse cervical branches* of the subclavian artery run outward parallel with the clavicle, the former behind, the latter just above it where its pulsation may usually be felt. The former is usually below and the latter above the line of incision. The *supraclavicular nerves* descend in front of this triangle. The **subclavian vein** *lies* below, internal to and

in front of the artery and under cover of the clavicle. To avoid injury to the vein the *aneurysm needle* should be *passed* from below and in front, to avoid including a nerve cord it should be passed from above and behind, and many consider that the latter avoids the greater risk.

At the inner end of this triangle the *subclavian vein* is separated from the artery by the *scalenus anterior*. Behind the latter the *artery* lies in contact with and grooves the *dome of the pleura* and the apex of the lung. These structures should be carefully avoided in passing the ligature. Strict asepsis should be observed to avoid inflammation of the pleura and empyema. The *pleura* has also been *opened* in removing deeply seated tumors at the base of the neck, and, together with the lung, has been wounded in stab wounds of the neck and by bony fragments in severe fractures of the clavicle or first rib. *Abscess* in this part of the neck has opened into the pleura, and pleurisy has also followed cellulitis here. Hernia of the lung into the neck during violent paroxysms of coughing has been reported. For the position of the lung and pleura in the root of the neck see p. 241.

The brachial plexus can be *felt* and, in very thin subjects, even seen as a number of firm cords in the subclavian triangle. Its *upper limit* is shown by a line from the side of the cricoid cartilage to a point a little external to the middle of the clavicle. It *lies* just above the subclavian artery, its lowest cord being partly behind the artery, and it emerges like the artery from between the anterior and middle scalene muscles. Hence it is exposed and may serve as a *guide in ligating* the subclavian artery. It has occasionally happened that a cord of this plexus has been included in the ligature in place of the artery, but the mistake is evident from the continued pulsation in the arteries of the arm. Rupture of the plexus occurs at birth (brachial birth palsy) or subsequently by a forcible separation of the head from the shoulder. This stretches and then tears first the upper roots, fifth and sixth, and then, if the force continues, the lower ones as well. The plexus may be reached by an incision in this triangle from the posterior border of the sternomastoid, at the junction of its middle and lower thirds, to the outer end of the middle third of the clavicle.

The **third portion of the artery** is the *seat of election* for ligature, for it is more superficial and has no branches and fewer vital relations. The **second part** lies deeply behind the scalenus anterior, on which lies the phrenic nerve. It includes the highest point of its curve, gives off *one branch* (superior intercostal), and is in close *relation* with the *pleura*. The **first portion** is *crossed* in front by the internal jugular, vertebral, and the commencement of the innominate veins, and on the right side by the pneumogastric and a loop of the sympathetic nerve. On the left side the thoracic duct arches over it. The subclavian vein is below and in front of it, and it gives off three large *branches*. *Below and behind* it are the pleura and lung and, on the right side, the recurrent laryngeal nerve. Hence and because of its deep situation it is not well suited for the application of a ligature.

After ligature of the second or third portions of the subclavian the

collateral circulation is established and carried on principally through the *anastomoses*, (1) of the suprascapular and posterior scapular with the acromiothoracic, subscapular and dorsalis scapulæ; (2) of the superior intercostal, aortic intercostal, and internal mammary with the long thoracic and the scapular arteries; (3) of small branches in the axilla.

Cervical ribs when present usually occur on both sides, sometimes on one side only. As a rule, they are articulated with the *seventh cervical vertebræ* and its transverse process, but sometimes they are fused with it. They may be very short, when they are often mistaken for *exostoses*, or they may extend well forward and be connected by bony, cartilaginous, or fibrous union with the first rib, its cartilage, or the sternum. In such cases the *subclavian artery* and *brachial plexus* pass over them, and the anterior, and sometimes the middle, scalene muscles are attached to them. The distinct *pulsation* of the artery at a high level in such cases may lead to a diagnosis of *aneurysm*, and, in fact, the latter condition seems to be not uncommonly associated with cervical ribs. The rib may form a distinct projection in thin persons, but, as a rule, it causes no *symptoms*. Sometimes, however, the circulation in the arm and the function of the branches of the brachial plexus is interfered with, apparently as the result of *pressure* by the ribs or of the *sharp bend* in the artery, and hence *removal* of the rib is indicated.

The anterior cervical triangle, in front of the sternomastoid, is *subdivided* by the digastric muscle above and the anterior belly of the omohyoid below into three smaller triangles.

The submaxillary triangle, or the upper one of these three, is *bounded* above by the lower border of the jaw and the line of this continued back to the mastoid process, below by the posterior belly of the digastric muscle and the hyoid bone, in front by the median line. It corresponds to the *suprahyoid region* of some authors. Its posterior angle belongs to and has been described under the parotid region. The *posterior belly of the digastric* muscle coincides with a *line* from the mastoid process to a point just above the junction of the great cornu and body of the hyoid bone.

In the normal position of the head this region lies in a nearly *horizontal* plane which accounts for the rarity of wounds here. When the head is extended, as it is in operations on this region, the latter is *oblique* from above downward and inward. **In incisions** into it we meet the **following layers** in succession: (1) skin; (2) platysma, with a connective-tissue layer on either side; (3) the superficial layer of the deep cervical fascia forming a sheath for (4) the submaxillary gland; (5) the muscular floor of the triangle, with vessels and nerves covered by a deeper layer of fascia which is attached to the hyoid bone and the mylohyoid ridge and forms a sheath for the digastric muscle.

The **platysma** is quite closely *connected with the skin*, so that the *edges of wounds* crossing the course of the muscle are likely to be turned in. Owing to the loose tissue beneath the muscle the skin and platysma may be readily used as a *flap*, and the flap so formed can be freely dis-

placed to cover defects in the lower lip and lower part of the face. But to cover defects in the lips or cheek such flaps possess the disadvantage of not being lined by mucosa, so that the final results are disappointing, owing to the adhesions and contraction of the flap (see p. 111). The amount of *fat* between the skin and deep fascia is very variable. There is often a diffuse deposit of fat, especially in the area between the chin and the hyoid bone, producing the so-called *double or triple chin,* thus converting the normal concavity of this region into a convexity.

The **superficial layer of the deep fascia** splits to enclose the *submaxillary gland* in a *fibrous sheath* and is *adherent* to the lower border of the jaw and to the hyoid bone. It is *continuous* laterally with the sheath of the sternomastoid and of the parotid gland, and in the median line with the similar layer of the opposite side. It is connected with the thick *fascial band* from the sternomastoid to the angle of the jaw, which separates the submaxillary from the parotid sheath.

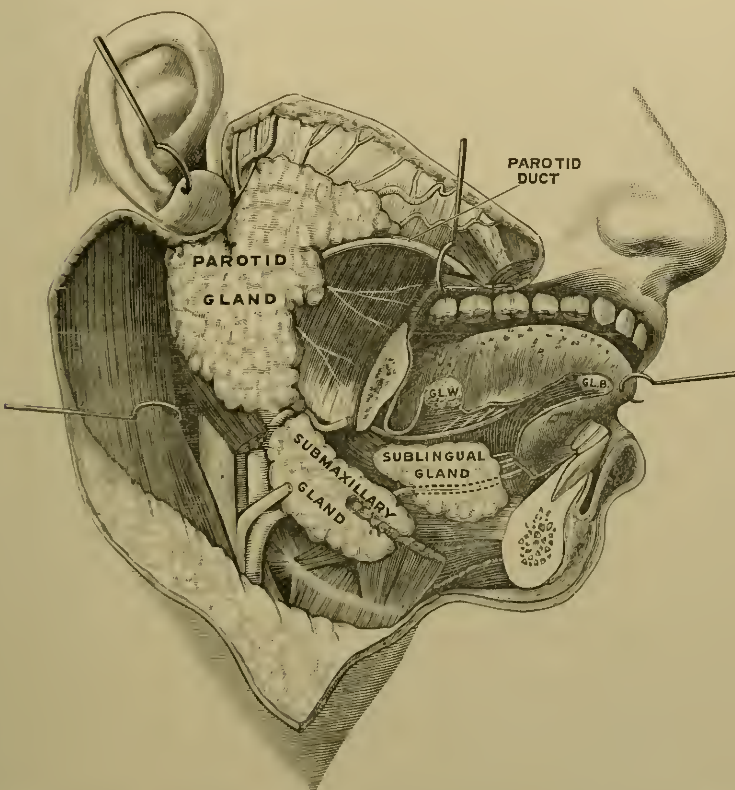
The submaxillary gland differs from the parotid in that its fibrous septa are not closely connected with the inside of its sheath, but it is separated from its sheath by loose connective tissue, so that it can be readily enucleated. The submaxillary gland is *seldom inflamed* primarily, though of all salivary glands it is most frequently the seat of *calculi,* which by obstructing the duct may produce sudden, recurring attacks of acute, painful *swelling* of the gland, sometimes accompanied by suppuration.

Beneath the fascia covering it and along the lower border of the jaw from the angle to the attachment of the digastric are the three to six *submaxillary* **lymph nodes,** on the surface of the gland, which receive lymphatics from the upper lip and the lateral part of the lower lip, the forepart of the lateral border of the tongue, the gums, the nose, the cheek, and the nasal half of both eyelids. Hence these nodes may be *affected* in any inflammatory affection or malignant newgrowth of these parts, and the enlarged or broken-down nodes require *opening or removal* according to circumstances. When these lymph nodes are removed it is often impossible to spare the gland, especially in cancerous conditions, and the entire contents of the digastric triangle are then removed together. In this procedure the most *important structure in relation* to the gland is the **facial artery,** which grooves its posterosuperior part, passing from its deep surface to the border of the jaw, just in front of the masseter. The general *direction* of the tortuous facial artery is between the latter point and its origin, just above and outside the tip of the great cornu of the hyoid bone, passing beneath the posterior belly of the digastric in its course. The **facial vein,** usually separated from the artery by the submaxillary gland, the posterior belly of the digastric, the stylohyoid muscle, and the hypoglossal nerve, *crosses* superficial to the artery to become more *posterior* at the border of the jaw. The *submental branch,* given off from the artery beneath the gland, runs forward on its deep surface.

When *enlarged,* the posterior extremity of the gland, grooved by the facial artery on its deep and superior aspect, may *overlap* the *external carotid,* from which it is *separated* by the posterior belly of the digas-

tric, the stylohyoid, and the band from the sternomastoid to the angle of the jaw. The gland lies partly hidden beneath the mandible. Its **accessory portion and duct** (*Wharton's*) (Fig. 49) (see page 119) pass forward in the floor of the mouth on the deep surface of the mylohyoid. Notice the close relation between this region and the floor of the mouth; inflammatory affections may spread from one to the other behind the mylohyoid. In this connection it should be remembered that the commonest

Fig. 49



The salivary glands. The right half of the body of the mandible has been removed. Wharton's duct is outlined by dotted lines beneath the sublingual gland. (Gerrish, after Testut.)

cause of *abscess* in the submaxillary region is *dental caries* followed by alveolar periostitis of the mandible (see page 112). Inflammation of the submaxillary gland and of the lymph nodes within its sheath, or the abscess resulting therefrom, is more circumscribed than the last-mentioned abscesses, and in opening submaxillary abscesses it should be remembered that the facial vessels and their branches are on the deep surface of the sheath and not exposed to injury.

The two bellies of the digastric below and the jaw above frame a

deep *triangle* lodging the submaxillary gland. The *floor* of this triangle is formed by the mylohyoid and hyoglossus muscles from before backward. Passing forward on the latter muscle is the *hypoglossal nerve,* accompanied by the *ranine vein* (Fig. 50). The **lingual artery** has much the same course, at a somewhat lower level, but it lies beneath the hyoglossus and upon the genioglossus muscle. This artery, arising opposite the tip of the great cornu of the hyoid, runs forward just above that process and is usually ligated in the "**lingual triangle.**" This triangle is *bounded* above by the hypoglossal nerve, in front by the posterior border of the mylohyoid, and behind and below by the posterior belly of the digastric (Fig. 50). It is readily exposed on turning up the submaxillary gland. The lingual artery is here *reached* by separating the more or less vertical fibers of the rather thin hyoglossus muscle, at right angles to which it runs. It is accompanied by one or several venæ comites.

To include the *dorsalis linguæ branch* it has been advised by Farabœuf and others to ligate the *first portion* of the artery, behind the hyoglossus muscle, near whose posterior border this branch is given off and passes upward. For this purpose the end of the great cornu of the hyoid bone is our guide, to which the posterior fibers of this muscle are attached. This part of the artery is *crossed by* the hypoglossal nerve, the facial and lingual veins, and the digastric and stylohyoid muscles.

The **sublingual artery**, usually given off at the anterior border of the hyoglossus, may sometimes arise in the lingual triangle, and might then be ligated in place of the trunk, so that the circulation on the same side of the tongue would not be controlled by the ligature. This is probably not the common cause of hemorrhage in operations on the tongue after ligation of the lingual, but rather an *anomaly* wherein the lingual on one side is small and its place is taken by a large branch from the opposite lingual.

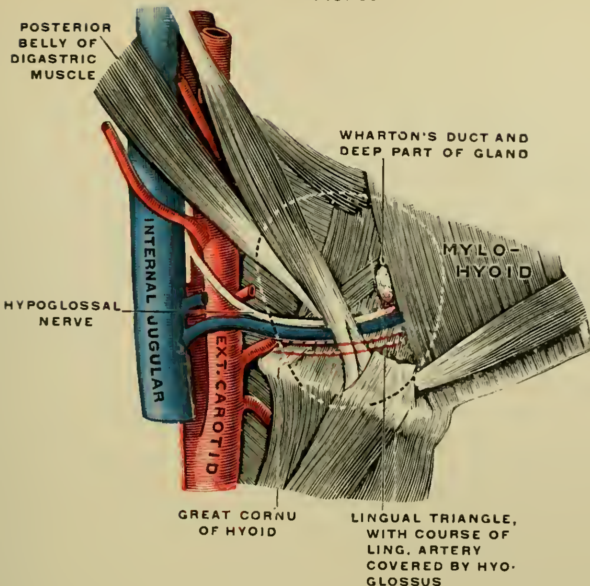
Underneath the deep fascia beneath the chin, in the triangle between the anterior bellies of the two digastrics and lying on the mylohyoid muscles, are usually two (1 to 4) submental **lymph nodes**, which receive vessels from the middle of the lower lip and gums, the floor of the mouth, the tip of the tongue, and the chin, and may be enlarged in affections of these parts.

The submaxillary gland and its neighboring lymph nodes are comparatively superficial and may be easily *reached,* for removal or for elevation to expose the lingual triangle, by a *curved incision* from just below the angle of the jaw to the body of the hyoid bone and up toward the symphysis. Kocher's so-called "**normal incision**" for the upper lateral cervical triangle passes from in front of the tip of the mastoid to the middle of the hyoid bone and lies just below the digastric and the other suprahyoid muscles. It avoids important nerve trunks, which lie above or posteriorly, or can be so retracted, for those crossing it can be retracted posteriorly, and it gives access to the bifurcation and branches of the great vessels. It may be used to expose almost any structure in this region, and leaves a narrow and unnoticeable cicatrix.

The subhyoid region is divided into the *two carotid triangles* by the anterior belly of the omohyoid muscle. The latter follows a line from

PLATE VII

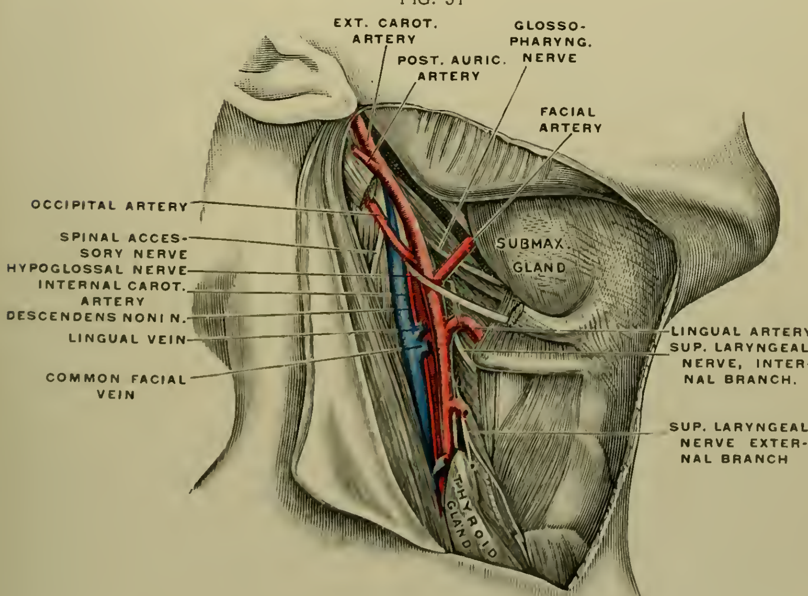
FIG. 50



Submaxillary Triangle and the Deep Relations of the Submaxillary Gland. Testut.)

Dotted white line indicates the position of the gland, dotted red line the course of the lingual artery beneath the hyoglossus.

FIG. 51



Structures of the Upper Part of Neck in the Superior Carotid and Submaxillary Triangles. (Zuckerkandl.)

The sternomastoid muscle is retracted somewhat backward, the digastric is divided and the omohyoid removed.

the side of the body of the hyoid at its lower border to the anterior border of the sternomastoid at the level of the cricoid cartilage, where it crosses in front of the common carotid and behind the sternomastoid.

The superior carotid triangle is *bounded* behind by the sternomastoid, above by the posterior belly of the digastric, and below and in front by the anterior belly of the omohyoid. Its *floor* is formed by the thyrohyoid, hyoglossus, and inferior and middle constrictor muscles of the pharynx. It *contains*, beneath the skin, the platysma, and the superficial and middle layers of the deep cervical fascia, the lower portion of the external carotid with the commencement of its lower five branches, and, beneath the anterior margin of the sternomastoid, the upper end of the common carotid and the lower part of the internal carotid.

The **superior thyroid artery** arises a little below the great cornu of the hyoid and runs downward and forward to the back part of the thyroid cartilage and the upper and outer part of the thyroid body. It is superficial only at its commencement. Beneath it is the *superior laryngeal nerve*, whose internal branch, with the superior laryngeal branch of this artery, pierces the thyrohyoid membrane. Its *sternomastoid branch*, arising about 12 mm. ($\frac{1}{2}$ in.) from its origin, and crossing the upper end of the common carotid to reach the sternomastoid muscle, is divided in incisions along the anterior border of the latter.

The **occipital artery**, arising at the same level as the facial (p. 136), but from the posterior aspect of the artery, passes upward and backward to the interval between the mastoid process and the transverse process of the atlas. It finally enters the scalp with the great occipital nerve midway between the mastoid process and the external occipital protuberance, and follows thence the line of the lambdoid suture. The facial and lingual branches have already been referred to.

The inferior carotid triangle is *bounded* above by the anterior belly of the omohyoid, behind by the sternomastoid, and in front or mesially by the median line. The carotid triangles are so called from their containing the carotid vessels, which, strictly speaking, are in great part behind these triangles under cover of the anterior border of the sternomastoid.

The Great Vessels.—The **line of the carotid** is from the sternoclavicular joint to a point midway between the angle of the jaw and the mastoid process. The **common carotid** *extends* up to the upper border of the thyroid cartilage, where it bifurcates into the external and internal carotids. At its point of *bifurcation* it presents a slight *dilatation*, which is the most common situation for *aneurysms*, for there appears to be increased resistance to the blood current here. Such an aneurysm may demand the *proximal ligature* of the carotid. The carotid, having no collateral branches, is also the vessel best adapted to the *distal ligature* (Basador's method), for by occluding the artery it prevents the blood passing through the aneurysm. It is most often practised for aneurysms in its lower part, where they are not uncommon. *Wardrop's operation*, or the distal ligature of large branches for aneurysm of a main trunk, has been tried here, and is now limited to the ligature of the carotid, and the third portion of the subclavian for aneurysms of the innominate, or occasionally

of the aorta. But as there are large branches given off from the first and second portions of the subclavian, which under the conditions present can scarcely be ligated, the success of this method is not so great as it might otherwise be.

The **common carotid** is now **ligated** mainly for aneurysm or wound of the artery itself. The *external or internal carotid,* instead of the common carotid, is now *ligated* to check hemorrhage from their branches due to wounds, to prevent hemorrhage in the removal of neoplasms, and to check the growth of the latter. As the ligation of the common carotid has been followed by cerebral symptoms (hemiplegia, cerebral softening, etc.), in about 25 per cent. of the cases the temporary control of the vessel by a clamp tightened only enough to stop the circulation has been employed to prevent hemorrhage in extensive operations on the head and neck. The *common carotid* may be secured at any part in the neck, but the **place of election** is just above the omohyoid, where it is superficial, being covered only by the skin, platysma, and superficial and middle layers of the deep cervical fascia.

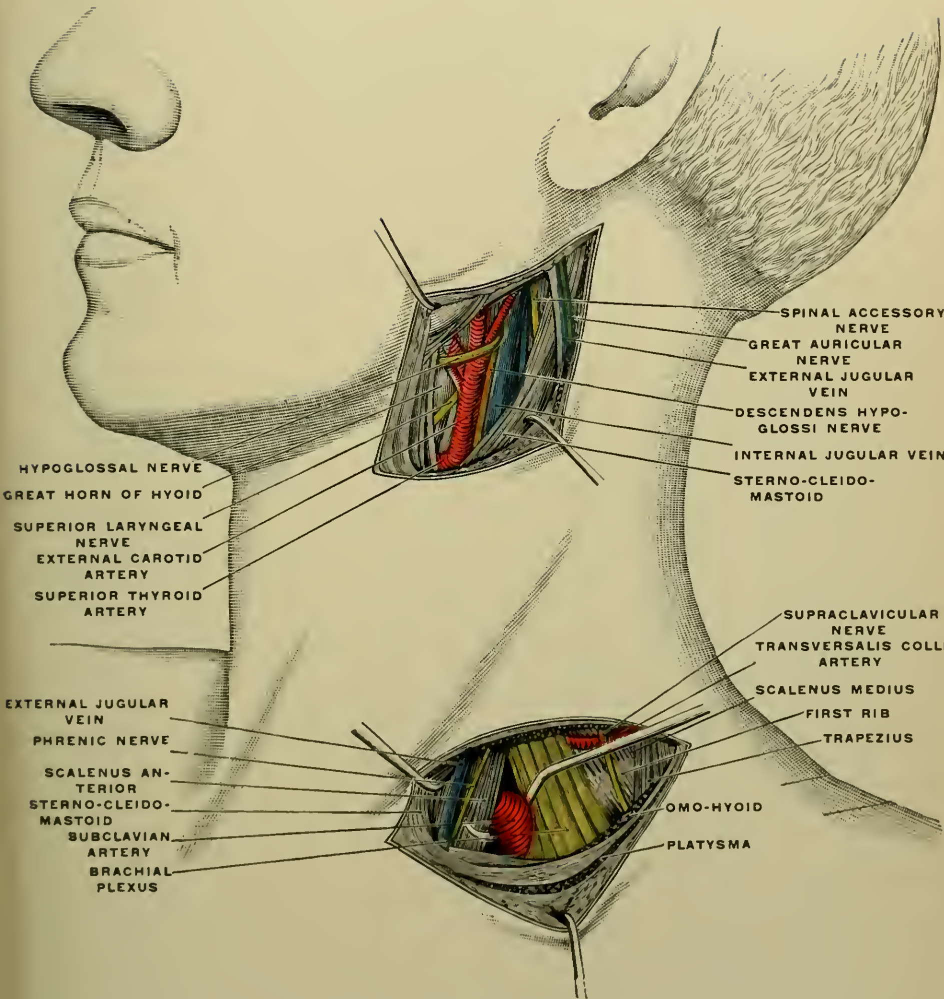
The **incision** is carried along the *anterior border* of the *sternomastoid,* with the centre opposite the cricoid cartilage. A communicating vein between the facial and the anterior jugular veins may be met with in the line of incision. After incising the superficial layer of the cervical fascia along the anterior border of the sternomastoid, we meet the *omohyoid* crossing obliquely the line of incision at the level of the cricoid cartilage. Then, incising the middle layer of the cervical fascia above the omohyoid in the same line, we expose the *carotid sheath,* which is here crossed by the *sternomastoid artery* and sometimes by the superior thyroid veins. The middle thyroid veins may also cross it here, but usually under the omohyoid muscle. A valuable guide to the artery, about the crossing point of the omohyoid, is the *carotid tubercle* or anterior tubercle of the sixth cervical vertebra, directly over which lies the artery and against which it may be compressed, without compressing the vertebral, which here occupies its bony canal.

This tubercle serves also as a *guide* to the **vertebral artery,** which *lies* on the transverse process of the seventh cervical vertebra just below it, *crossed by* the inferior thyroid artery and, on the left side, by the thoracic duct. It is less often tied than formerly. *Below the omohyoid* the carotid artery lies more and more deeply, as we follow it to the base of the neck, being overlapped in front by the sternohyoid and sternothyroid muscles and to some extent by the thyroid body, especially if the latter is enlarged. The inferior thyroid artery and the recurrent laryngeal nerve cross behind it. *Near its lower end* the anterior jugular vein crosses in front of it.

The **carotid sheath,** *derived* from the deep layer of the deep cervical fascia, encloses the internal *jugular vein* and the *vagus nerve* in addition to the artery. The sheath should be *opened* from the inner side to avoid the thin-walled vein, which is external and, being nearly twice the size of the artery, overlaps the latter anteriorly. On the right side *the vein,* which is commonly larger than that on the left, becomes a little separated

PLATE VIII

FIG. 52



Surgical Relations of the External Carotid, Lingual, Facial, Occipital, Subclavian, and Transverse Cervical Arteries. (Kocher.)

from the artery at the root of the neck, while on the left side the vein overlaps the artery still more at this point. Although each of the three occupants of the sheath has its own special investment, there is danger of wounding the vein in passing the *aneurysm needle*, and to avoid this danger the latter is *passed from without* inward, after carefully separating the vein and artery and taking care not to include the vagus nerve.

In exposing the sheath of the carotid the **descendens noni nerve** is found in front of it, inclining gradually from the outer to the inner side. Care should be taken to *avoid it*, as it supplies the infrahyoid muscles. It is sometimes found within the sheath. On the inner side of the artery close to its bifurcation is a small, ovoid, brownish-red body, 5 to 7 mm. long, known as the *carotid body*. It contains many nerve fibers and cells and is closely associated with the sympathetic system. It may be the starting point of a malignant newgrowth, especially of the variety known as perithelioma.

As before stated, the **external carotid** is now **ligated** for many conditions for which the common carotid was formerly tied. Thus it is ligated for wound or aneurysm of its branches, but it is better to tie both ends of bleeding vessels, as the anastomosis with the branches of the opposite external carotid is very free. It is also ligated as a preliminary measure in certain operations (like excision of the parotid, maxilla, etc.) and as a palliative measure in malignant neoplasms to starve them or prevent hemorrhage. For the latter purposes *excision* is more effective than ligature. In this operation the branches are divided between two ligatures; a ligature is applied at its lower end and as high up as the circumstances of the case permit, and the portion between these ligatures removed. Ligature, and especially excision, of the external carotid is less easy but safer and more satisfactory than ligature of the common carotid.

The **line of the external carotid** inclines forward from the line of the sternomastoid to reach a point beneath the angle of the jaw. *In the natural position*, when the angle of the jaw about touches the sternomastoid, the *line of the artery* nearly corresponds to the anterior border of the muscle, but *in the extended position* of the head, in which the operation is done, the line of the artery is from the angle of the jaw to the sternomastoid at the upper border of the thyroid cartilage.

The **incision** for ligature or excision may be made in this line or across it, in the line of Kocher's normal incision (p. 138). In its *lower part* the artery is comparatively *superficial*, being covered by the same layers which cover the upper part of the common carotid (p. 140), but it soon becomes more deeply placed and passes beneath the digastric and stylohyoid muscles and then internal to and within the parotid gland. Below the digastric, which crosses it about 3 cm. ($1\frac{1}{4}$ in.) above its commencement, it is *crossed* by the hypoglossal nerve and below this by the facial and lingual veins, usually as a common trunk, which is often joined by the superior thyroid vein. The **place of election** for ligature is between the superior thyroid and the lingual branches, or opposite the tip of the great cornu of the hyoid bone. Through the *same incision* the *six lower branches* of the external carotid can be *ligated* at their origin.

In the first part of its course the external carotid is situated internal (mesial) and anterior to the internal carotid, in the loose connective tissue in which both are lodged, hence the question may arise whether the vessel exposed is the internal or external carotid. The *following points* help us to *distinguish* the *external carotid:* (1) the presence of branches; (2) the stoppage of pulsation in its branches from compression of the artery; (3) contact with the hypoglossal nerve which crosses it just below the origin of the occipital branch; and (4) its near relation to the great cornu of the hyoid.

In *passing* the *aneurysm needle* care is needed to avoid the superior laryngeal nerve which passes beneath the artery in this situation. The artery may also be tied beneath or above the digastric, but it lies deeper above the muscle and is more difficult to expose. Some distance above the muscle the glossopharyngeal nerve passes obliquely beneath the artery. For the various *anomalies* and variations of the external carotid descriptive text-books may be consulted, but one may be mentioned which I have met with in a preliminary ligature of this vessel, *i. e.*, the absence of an external carotid trunk and the giving off of the branches in an axis manner.

The **internal carotid** may be *exposed* and *ligated* in much the same manner and with the same precautions as the common carotid, of which it appears to be the continuation as to its course and relations. What has been said above as to the relations of the common carotid and its branches is equally and more frequently useful in the numerous operations for various conditions in which these vessels are exposed and avoided, as in *tuberculous lymphadenoma* of the neck, etc.

The **internal jugular** and the other large veins of the neck, as well as the subclavian and axillary veins, are subject to the **respiratory wave** (or venous pulse). This is *indicated* by their being more or less emptied in inspiration and distended in expiration, and is *due* to the alternately decreased and increased intrathoracic pressure acting on the right heart and the venous trunks. When one of these veins is wounded it may be prevented from completely collapsing by its attachment to the deep fascia, and *air* is liable to be drawn in during the *inspiratory aspiration* of its contents, provided the wound is dry or the vein is not immediately compressed between the wound and the heart. Nothing prevents the passage of this air to the right auricle of the heart. Hence pressure should be at once made at the wound of the vein or on its cardiac side. The danger of *aspiration of air* into veins has been much exaggerated, and it is not so frequent an accident as is generally supposed, and as might be expected from the above. It is *not likely* to happen if the peripheral flow of blood to the wounded spot is unobstructed, for then the blood covers the opening in the vein, or if the wall of the vein is healthy and its wound is not held open, for then atmospheric pressure causes it to collapse. It is *favored* by the elevation of the wounded part and it may occur beyond the limits of the venous pulse. *Large amounts* of air aspirated may *cause death* rapidly by overdistention and paralysis of the right heart, or more slowly by asphyxia from air embolism of the pulmonary vessels. The entrance of smaller quantities of air is usually recovered from.

Phlebitis and thrombosis of the internal jugular may occur secondary to infective intracranial sinus thrombosis and call for ligation of the vein to prevent infective emboli reaching the lungs. The vein may also be excised with impunity when it is essential to the thorough removal of a malignant growth or the lymph nodes, secondary to such a growth elsewhere, adherent to the vein. After ligation of the vein the blood from that side of the head passes through the transverse sinuses to the internal jugular of the opposite side.

The *cervical portion* of the **sympathetic gangliated cord** lies close behind the carotid sheath and in front of the prevertebral fascia. It lies slightly internal to the vagus nerve, which is within the sheath, more behind the artery. It consists of **three composite ganglia** united by intervening nerve cords.

The **superior cervical sympathetic ganglion**, 2.5 to 3.75 cm. (1 to $1\frac{1}{2}$ in.) long, *lies* in front of the second and third cervical transverse processes. It is connected above with the carotid and cavernous plexuses, below with the smaller **middle or thyroid ganglion**, *situated* where the cord crosses in front of and behind the inferior thyroid artery, at the level of the sixth cervical vertebra. The middle is connected with the inferior ganglion by cords which pass both behind and in front of the subclavian artery. The **inferior ganglion**, larger than the middle, is deeply *placed* between the seventh cervical transverse process and the neck of the first rib, behind the vertebral artery.

As far as we now know the **functions** of the *cervical sympathetic*, it contains dilator fibers of the pupil, motor fibers of the involuntary muscles of the orbit and eyelid, vasomotor fibers of the head, neck, and face, accelerator fibers of the heart, besides secretory fibers of the salivary glands. *Paralysis* of the cervical sympathetic, as after resection of the ganglia, causes contraction of the pupil, ptosis, recession of the eyeball, congestion of the face, head, and neck, with increase of tears, nasal mucus, saliva, and sometimes of perspiration, and decrease in the pulse rate. Many of these symptoms are temporary. Irritation of the nerve causes an opposite condition. From theoretical considerations the *excision* of the superior or all the cervical ganglia has been proposed for glaucoma, exophthalmic goitre, epilepsy, and tic douloureux.

The *superior ganglion* alone requires *removal for glaucoma*, and it is *followed by* contraction of the pupil, retraction of the globe, some ptosis, and the diminution of the ocular pressure (see p. 78). The contraction of the pupil is temporary, lasting only a few days, the ptosis is permanent. As the superior ganglion supplies the vasoconstrictors of the carotid region only, the inferior ganglion, which does the same for the region of the vertebral artery, must also be removed to *alter the cerebral circulation in epilepsy* and improve the nutrition of the brain, by substituting hyperemia for anemia. The results in epilepsy have not been very satisfactory. For *exophthalmic goitre* the resection of the superior ganglion for exophthalmos and the middle and inferior for the goitre and tachycardia have given some encouraging results. Hence for epilepsy and Graves' disease the resection of the entire cervical sympathetic is advisable, but from the

anatomical relations above given it is evident that the operation on the middle and inferior ganglia is one of some delicacy. The *cervical sympathetic* may be *exposed* by an *incision* along the anterior or posterior border of the sternomastoid more readily than might be supposed. *Unilateral division* of the *vagus* nerve may be made without danger to life, or even without disturbance to the patient if the nerve is first blocked by cocaine or a preliminary hypodermic of atropine is given to prevent the inhibitory action on the heart.

The Hyoid Bone.—**Fracture** of this is rare, but it may occur in hanging or from blows, falls, throttling, or even muscular action. Its usual *situation* is at or near the junction of the great cornu with the body of the bone. Movement of the fragments *causes* pain, hence this is felt on speaking, swallowing, opening the mouth, moving the tongue, or on pressure, as most of the extrinsic muscles of the tongue and the depressors of the jaw are attached to it. It is not often serious of itself, but its associated injuries may be fatal.

Extending between the upper border of the thyroid cartilage and the upper and posterior margin of the hyoid bone is the **thyrohyoid membrane**, about 3 to 4 cm. ($1\frac{1}{4}$ to $1\frac{3}{4}$ in.) in height. Owing to its attachment to the superior border of the hyoid, the larynx may be drawn up behind the latter bone. In front of the membrane, between it and the back of the body of the hyoid bone and extending somewhat below the middle of the latter, is the **thyrohyoid bursa**, which when cystic forms a *median tumor* just beneath the hyoid. If this should be opened, as in case of suppuration, a *fistula* is likely to result unless the lining membrane has been excised or destroyed, for the constant movements of the parts in swallowing prevent the walls of the cyst from adhering together. A similarly placed cyst or fistula, but lined with columnar epithelium, is due to the persistence of the thyroglossal duct. *Mesially* the membrane is subcutaneous except for the intervening cervical fascia, *laterally* it is covered by the thyrohyoid and sternohyoid muscles.

Behind the thyrohyoid membrane, and separating it from the epiglottis, is a mass of *fatty connective tissue* limited superiorly by the mucous membrane at the base of the tongue. Through this tissue and the thyrohyoid membrane the *transverse incision* is carried in **subhyoid pharyngotomy**, keeping close beneath the hyoid bone to avoid the *superior laryngeal nerve* (internal branch), which pierces the membrane on each side. As this is the *sensory nerve* of the larynx, wounding it increases the risk of foreign substances passing into and through the larynx, which involves the danger of aspiration pneumonia. By this operation we may expose and operate upon the larynx above the vocal cords, especially posteriorly, and the lower part of the pharynx.

It is through this thyrohyoid membrane and its over- and underlying parts that **cut-throat wounds** are most likely to occur. In such cases the anterior jugular vein, superior thyroid artery and nerve, and, if near the hyoid bone, perhaps the lingual artery, would be *divided,* besides several muscles, etc. In a *deep wound* the pharynx would be opened and the epiglottis cut near its base. The latter are *serious complications,* for the

free end of the epiglottis may obstruct the glottis and the blood flowing into the larynx and trachea may also cause asphyxia. Suicidal throat wounds made by right-handed persons are *generally oblique,* passing from the left downward and to the right, and the first part of the wound is often shallow. If the wound be *above the hyoid bone,* the anterior jugular vein, lingual artery, branches of the facial artery, the hypoglossal and lingual nerves and the submaxillary gland, besides several muscles, would be cut. Among the divided muscles those attaching the tongue to the jaw, are likely to be cut so that the tongue is liable to fall back upon the larynx and cause suffocation. The tongue itself may be cut and the floor of the mouth freely opened.

Next in frequency to wounds in the thyrohyoid space are those involving the trachea or larynx, in which the anterior jugular vein, thyroid gland, superior and inferior thyroid arteries and veins, middle thyroid veins, recurrent laryngeal nerves, trachea and esophagus, besides the infrahyoid muscles, are cut. There is *danger of blood* getting into the *trachea and bronchi* in sufficient quantity to produce suffocation. When the trachea is severed or widely opened the voice is lost.

In all such wounds of the neck, suicidal or otherwise, the *great vessels often escape* in a surprising manner, being protected in part by their depth and mobility, and in part by the projecting thyroid cartilages and by the contraction of the sternomastoid muscle pressing the vessels back. Of course, in some cases the great vessels are wounded, usually with a rapidly fatal result. In some cases of *gunshot and punctured wounds* the vessels seem to have been pushed aside and to have owed their safety to their mobility. The great vessels are more easily wounded in wounds across the cricothyroid space or the upper part of the trachea than in wounds made elsewhere in the neck with equal force. Some wounds at the side of the neck have involved a large part of the *brachial plexus* without other important structures. The **chief dangers** of wounds of the neck are **hemorrhage and suffocation,** the latter from blood in the trachea and bronchi or from obstruction of the glottis by the falling back of the tongue or the wounded epiglottis.

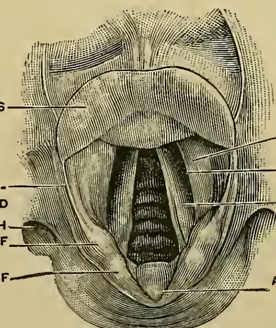
The Larynx.—The larynx in its median position below the thyrohyoid membrane can usually be readily *felt,* especially in males in whom it is larger, so that it stands out between the two sternomastoids. The most prominent part is the anterior mesial border of the thyroid cartilage, 2 to 3 cm. ($\frac{4}{5}$ to $1\frac{1}{5}$ in.) in height, whose upper angle is known as the pomum Adami or *Adam's apple.* A bursa has been described in front of this prominence by Béchard. In women and children, in whom the neck is more rounded and the larynx is smaller, the latter is less prominent but is usually distinctly felt, and is an important landmark.

The relative **position** of the larynx varies with the position of the neck and the age of the patient. Thus the *lower border of the cricoid cartilage* varies from a point opposite the fifth to one opposite the seventh cervical vertebra, being higher in the young and when the neck is extended. In the *median line* the larynx is *covered* only by the skin and cervical fascia (the anterior and middle layers blended into one), *laterally* by the infra-

hyoid muscles and the thyroid gland. The *superior aperture* of the larynx or the space between the aryteno-epiglottic folds corresponds to the superior border of the thyroid cartilage, the *glottis* to the junction of the superior and middle thirds of its anterior border, the laryngeal pouches to about its superior third.

With the **laryngoscope** may be *seen* (Fig. 53) the *triangular superior aperture* of the larynx placed very obliquely from above and in front downward and backward. Its *base* is at the epiglottis in front, its *sides* are formed by the aryteno-epiglottic folds, in which are two eminences corresponding to the cornicula and cuneiform cartilages, and its *apex* is at the arytenoid commissure of mucous membrane. Between each aryteno-epiglottic fold and the ala of the thyroid cartilage is the shallow depression of the *pyriform sinus,* in which small foreign bodies are frequently lodged. More deeply are seen the superior or *false* and the inferior or *true vocal cords* with the *ventricle* between the two pairs of cords. Below the glottis a little of the cricoid cartilage and more or less of the anterior

Fig. 53



Larynx viewed from above, the vocal cords and arytenoid cartilages widely separated. (Zuckerkandl.)

tracheal wall is visible, and, if the glottis is widely dilated, even the *bifurcation of the trachea* may be dimly seen. As the mirror is tilted, the image of the epiglottis is on its upper and anterior part, that of the arytenoids on the lower and posterior part, but that of either vocal cord is on the side to which it actually belongs.

The **glottis** (Figs. 47, 53) is the *narrowest part* of the interior of the larynx, *measuring* nearly 2.5 cm. (1 in.) anteroposteriorly in the adult male, and about three-fourths of that in the female and in the male before puberty. Approximately the *anterior two-thirds* of the glottis consists of the *true vocal cords,* the posterior third of the interval between the arytenoid cartilages, covered by mucosa. The transverse diameter may equal half its length in extreme dilatation. These dimensions are important in relation to the arrest of foreign bodies and the introduction of instruments.

On account of its narrow caliber, **foreign bodies** of the most varied character may be arrested here, either above or in the rima of the glottis,

according to their size. I have removed from a one-year-old baby through a high tracheotomy two pieces of egg shell which were caught in the glottis and hung down below it. The *mucosa* of the larynx, supplied by the superior laryngeal nerve, is so *sensitive* that it acts as a *sentinel*, at whose warning the glottis closes to keep out foreign bodies, but it is sometimes taken unawares and lets a foreign body through into the trachea. The *danger* of many such foreign bodies in the larynx or trachea is not so much due to the mechanical obstruction as to the *reflex spasm* of the glottis which they excite.

A peculiar *spasm of the glottis* of reflex nervous origin, perhaps due to indigestible food, dentition, or spinal disease, occurs in infancy under the name of **laryngismus stridulus** or laryngeal asthma. A similar condition of **spasm of the glottis** in adults may be due to the *pressure* of an aneurysm or a tumor *on the recurrent laryngeal nerve.* Such pressure in time paralyzes the nerve so that the vocal cord on the affected side cannot be approximated, and, consequently, the voice is hoarse or lost, a characteristic symptom of many aneurysms of the aortic arch. The opposite cord may, however, be made to reach beyond the median line in the effort at compensation.

The **caliber** of the *rima glottidis* may be diminished as the result of **strictures** from syphilitic, tuberculous, or diphtheritic ulceration which require the long-continued use of an intubation tube or sometimes a more radical operation.

The **shape** of the glottis varies from an extremely narrow vibrating *slit*, in the production of a high note, to an elongated narrow *triangle* with the apex forward, in quiet breathing, or a *lozenge-shaped figure* with a truncated posterior angle in deep respiration. These changes are due to the approximation or separation of the sides of the glottis by means of the approximation or separation of the arytenoid cartilages, and, in the production of the wider lozenge-shaped opening, by the rotation of their anterior angles, to which the vocal cords are attached. The glottis is *closed*, after inspiration, *to fix the diaphragm* in efforts of expulsion, as in defecation, urination, vomiting, and parturition.

The **mucosa** of the true vocal cords is covered by a thin stratified epithelium, beneath which there is no loose submucous connective tissue, hence there is little or no chance of acute edema of the glottis. The so-called "**edema of the glottis**" occurs in the submucous tissue above the glottis, especially in that of the *aryteno-epiglottic folds*, which is very abundant. This may rapidly swell in case of laryngitis or irritation by heat, caustics, injury, or neighboring inflammatory conditions, and cause obstruction of the superior aperture of the larynx, with dyspnea or even suffocation, especially in children in whom the larynx is small. The *mucosa is thickest* and the submucosa most abundant in the aryteno-epiglottic folds, the ventricles, the false vocal cords, and the under surface of the epiglottis, in the order given, and the degree of congestion and swelling in acute laryngitis varies correspondingly. The result of the swelling is a croupy cough and hoarseness or aphonia, with dyspnea in severe cases from obstruction or spasm. In some cases the swelling

affects chiefly the parts below the glottis. To relieve the extreme dyspnea due to edema of the glottis or the presence of false membrane, etc., *intubation* is very effective.

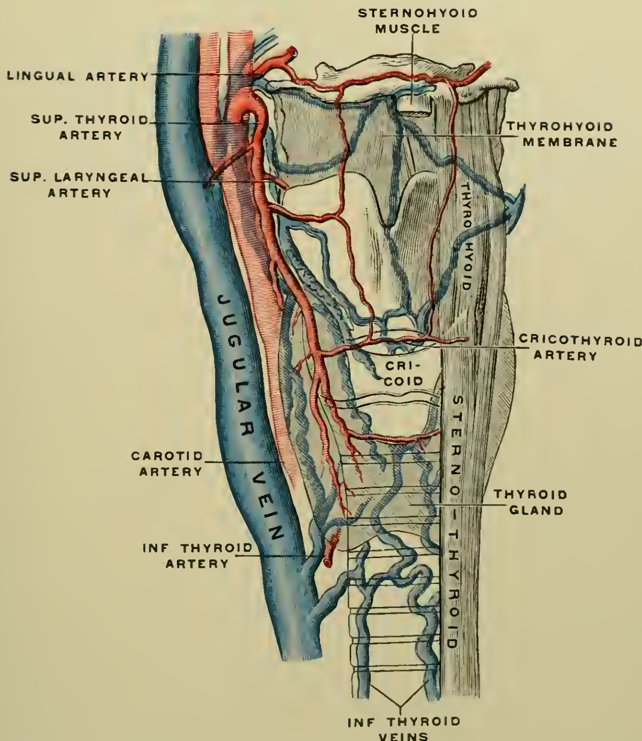
Laryngeal polypi of various kinds, either pedunculated or sessile, may grow on the vocal cords or other parts of the larynx and cause aphonia, cough, and more or less difficulty in breathing. They may be *removed* through the mouth, with the aid of the laryngoscope, through a subhyoid pharyngotomy or by *thyrotomy*. The latter consists of a median splitting of the thyroid cartilage, which must be done exactly in the median line so that the opening into the larynx shall be between the vocal cords, otherwise there is great danger of permanently impairing vocalization. This operation may also be applied to the removal of impacted foreign bodies and infrequent subglottic growths, to the treatment of some forms of stenosis, and to exploration in intralaryngeal growths.

The *thyroid, cricoid,* and *arytenoid cartilages* are composed of *hyaline cartilage,* and, like other structures composed of this variety of cartilage, are liable to *ossification,* especially in males after middle life. It occurs first in the thyroid and cricoid cartilages, commences near their articulation, and renders the larynx more liable to **fracture**. The latter occurs from lateral or anterior compression by blows, falls, throttling, etc. Fracture is, therefore, more common in the thyroid cartilage and in males on account of its size, shape, and prominence. The *thyroid cartilage* is commonly *fractured* at or near the median line. According to Dr. Rambaud, the *line of fracture* is usually to one side of the median line, owing to the fact that the two alæ of the thyroid are united in front by a thin median strip of cartilage, at whose junction with one of the alæ the fracture occurs. *Fracture of the cricoid* is less common and more serious, as it requires more violence. *Fracture* of the larynx is *dangerous* on account of the liability to *dyspnea* due to the aspiration of blood, spasm of the glottis, displacement of the fragments, and edema of the glottis. Hence in most cases *tracheotomy* should be *promptly done.* Owing to the fact that the larynx moves in deglutition, this act is very painful in laryngeal fracture. The *epiglottis,* like other elastic cartilages, is not liable to ossification, but it is a favorite site for *syphilitic ulceration.* Perichondritis may involve the cricoid and, less often, the thyroid cartilages as a sequel to typhoid fever or secondary to tuberculous or cancerous ulceration.

Excision of the larynx is sometimes done for malignant disease. After exposure by a *free median incision* the larynx is freed laterally from the sternothyroid and thyrothyoid muscles and more posteriorly from the stylo- and palatopharyngei and the inferior constrictor muscles. The superior and inferior laryngeal nerves are divided, and branches of the like named arteries. Then severing it from the trachea or the thyrohyoid membrane the larynx is separated from the pharynx and esophagus behind it, either from below up or above down, care being taken not to "button-hole" the esophagus. Occasionally only one-half of the larynx is excised. Aspiration pneumonia is a great menace. Preliminary tracheotomy is not necessary, for if the larynx is severed from the trachea

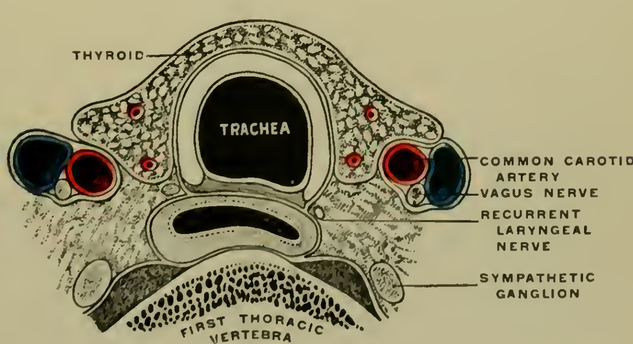
PLATE IX

FIG. 54



Superficial Vessels of the Infrahyoid Region, around the larynx, thyroid, and trachea. (Merkel.)

FIG. 55



Cross-section of Thyroid Body, Trachea, and Esophagus, showing their relations. (Testut.)

before the air passages are opened elsewhere the distal end of the trachea may be brought forward and a tube introduced temporarily.

Laryngotomy (cricotomy), or the *opening* of the larynx through the *cricothyroid membrane*, is sometimes performed in place of tracheotomy on account of the ease and rapidity of its performance. It is not applicable to *children* under puberty on account of the narrowness of the cricothyroid space, which in the adult is at most only about 12 mm. ($\frac{1}{2}$ in.) in height. The *cricothyroid branches* of the superior thyroid arteries *anastomose across this space*, and, though usually small, they occasionally cause serious and even fatal *hemorrhage*, which may be *obviated* by dividing the membrane transversely or by tearing the artery between two forceps. An objection to the operation is the proximity of the vocal cords, so that it is unsuited for cases where the tube is to be worn for long. In *adults*, in whom alone the operation is applicable, it is not advisable to divide the cricoid cartilage to gain more room, on account of the possibility of its being ossified and the little added room that it gives.

The **lymphatics** of the larynx pass mostly to the deep cervical glands, but in part to a node between the cricothyroid muscles, to one in front of the trachea, and to several small ones along the recurrent nerve. Of the **nerves** of the larynx the *superior* supplies *sensation* to the mucosa down to the glottis and *motor fibers* to the cricothyroid muscle, which makes the cords tense. The arytenoid muscle is supplied both by this and the recurrent laryngeal, which supplies all the other muscles. The inferior laryngeal also contains some sensory fibers.

Trachea.—*About half*, or 5.5 cm. ($2\frac{1}{4}$ in.), of the trachea is *in the neck*, between the cricoid cartilage, opposite the sixth cervical vertebra, and the episternal notch. This **length** varies with the age, and the length and position of the neck. Thus in extension of the neck it may be increased by 2 cm. ($\frac{3}{4}$ in.) in its cervical portion and 2.5 cm. (1 in.) altogether, owing to its elasticity (Braune). This **elasticity** allows it to accommodate itself to the movements of the neck, and also causes the lower end to retract when it is severed. The retraction is favored by the loose connective tissue in which it lies, and this also allows of considerable lateral mobility. This **mobility** is greater in children. It allows the trachea to escape from injury or the pressure of tumors on one side of it, and adds to the difficulties of tracheotomy. As the trachea passes somewhat backward, as it descends its *upper part* is *more superficial;* hence, when possible, tracheotomy should be performed here, for not only is it deeper but its relations are more complicated below.

Relations of Overlying Parts (Fig. 55).—**Above the thyroid isthmus**, which lies in front of the second, third, and fourth tracheal cartilages, the sternohyoid and sternothyroid muscles are separated by a slight interval, and the superficial and middle layers of deep cervical fascia form practically a single layer in the median line. The levator glandulæ thyroideæ muscle and the pyramidal lobe of the thyroid when present (p. 152) lie in front of the trachea. As the *thyroid isthmus* may leave uncovered above it but a single tracheal ring it must be *retracted downward* to allow a high tracheotomy. To permit this retraction the *fascia* connect-

ing it with the cricoid cartilage should be *divided* by a *transverse incision* over the latter, and then its downward retraction is easy. In *children* the thyroid *isthmus* is little more than connective tissue, and may be ignored or divided between two ligatures, and the latter may also be done in the adult. Abnormal branches of the superior thyroid artery or twigs of it to the pyramidal process, when present, may cross the upper tracheal rings, and a communicating branch between the superior thyroid veins may cross at the upper border of the isthmus.

Below the thyroid isthmus the superficial and middle layers of the deep cervical fascia are separated from one another by an interval filled with loose connective tissue and fat, in which there is a transverse anastomosis between the anterior jugular veins, just above the sternum. Below the thyroid gland the *superficial layer splits into two layers* attached to the anterior and posterior borders of the episternal notch and enclosing a triangular interval, so that there are *three fascial layers to incise* at this level. Beneath the middle layer of the deep fascia is a layer of fatty connective tissue in which the plexiform inferior thyroid veins, the thyroidea ima, when present, and, in infants under two years of age, the upper 1 cm. of the thymus gland lie in front of the trachea. At the very *root of the neck* the *left innominate vein* crossing the trachea may extend up above the sternum, especially when there is venous congestion or when the neck is extended, both of which conditions are usually present when tracheotomy is performed. The *carotids* crossing the trachea anterolaterally may occasionally overlap it in front to an abnormal degree and the left common carotid, when it arises from the innominate, may cross the trachea above the sternum. The infrahyoid muscles are here in close contact and the trachea is more movable.

Tracheotomy is called **high or low** according as it is above or below the isthmus of the thyroid body. The facts just recited, in addition to the depth from the surface and the greater danger of bronchopneumonia and of the sinking of pus into the mediastinum, make the **high operation always to be preferred.**

In either operation the *neck* should be *fully extended,* for this steadies the trachea, makes it more superficial, lengthens the neck and the portion of the trachea in the neck, and makes tense the structures in front. The chin is held in the same longitudinal line with the episternal notch and the **incision** is made *exactly in the median line.* The *cervical fascia* should be well and *freely divided* to avoid the not uncommon accident of passing the tube between the fascia and the trachea. The *trachea* should be *steadied* from above by a sharp hook in the median line as a guide to the latter and to the opening when made. Cases are reported where, from lack of such precaution, the trachea has been opened from the side or behind or even through the esophagus and where the opening when made could not be readily found again. The *opening* should be made by a thrust of the knife to insure the penetration of the lining mucosa, to avoid the mistake of passing the tube into the trachea between the mucosa and the fibrocartilaginous framework.

The **diameter** of the trachea *varies with the age* and to some extent

individually, and is of importance with reference to the size of the tracheotomy tube to be used. In the adult cadaver the greatest transverse diameter may vary between 18 and 25 mm. ($\frac{3}{4}$ to 1 in.), but in the living subject it is less. According to the observations of Symington and Guersant the following *diameters of the tube* are suited to the ages given: Under one and one-half years, 4 mm.; one and one-half to two years, 5 mm.; two to four years, 6 mm.; four to eight years, 8 mm.; eight to twelve years, 10 mm.; twelve to fifteen years, 12 mm.; adults, 12 to 15 mm. The tube should not be too curved lest the pressure of its sharp end cause an ulceration into the innominate vein or artery or the common carotid and occasion a fatal hemorrhage. I have known of one such case, and several are recorded.

The **difficulties of tracheotomy in children** *depend upon* the shortness of the neck, the small size of the trachea, its mobility and depth, the high level at which the great vessels frequently cross it, and the occasional presence of the thymus in front of it. The full length of the cervical portion of the trachea in a child of three to five years is about 3.75 cm. ($1\frac{1}{2}$ in.).

The *cartilages prevent* the *collapse* of the tube from internal suction and external atmospheric pressure in inspiration, and from the pressure of enlarged thyroids and other tumors. Constant pressure, as of a large goitre, may cause the gradual absorption of the rings beneath the area of pressure, so that serious compression may occur and a long, special form of tracheal tube may be required to avoid collapse of the trachea. Ossification of the tracheal cartilages commences at about forty to fifty years of age. In the child the trachea collapses on slight pressure, owing to the yielding character of the thin cartilaginous rings. Treves mentions a case where he saw the trachea of an infant bent on itself and invaginated into its lumen by the pilot of the tracheotomy tube.

The musculomembranous *posterior portion* of the tracheal wall is *in contact with the esophagus*, which deviates somewhat to the left in the lower part of the neck. The absence of cartilaginous rings between the trachea and esophagus avoids the pressure of the trachea upon the esophagus, which might impede deglutition. Impacted foreign bodies or malignant disease in the esophagus may cause serious difficulty in respiration by pressure on the posterior soft portion of the tracheal wall. These two tubes, connected together by loose connective tissue, allow movements of one upon the other at the same time that they move together in deglutition. The easily felt trachea is of great importance as a landmark in external esophagotomy in the neck. In the angle between them lie the *recurrent laryngeal nerves*, the right being more behind, the left to the side of the trachea.

The *common carotid arteries*, and the other contents of their sheaths, as well as the inferior thyroid and the vertebral arteries, are near enough to be said to be in relation with the trachea *on the sides*, but are not near enough to disturb the operator in tracheotomy, especially if he keep strictly in the median line and is careful to fix the trachea by a sharp hook in that line. In a low tracheotomy the great vessels are nearer the

sides of the trachea than they are above where the lobes of the thyroid gland intervene.

Foreign bodies in the trachea are usually *arrested* at its *bifurcation,* and if they pass beyond this it is into the right bronchus, as a rule (see p. 251). They entail a fatal result unless removed by coughing or by operation. Through a *low tracheotomy* they can sometimes be reached and removed by a long forceps as low down as the bifurcation, but more often they are expelled by a violent fit of coughing, through the wound or through the glottis, at the time of operation or subsequently. They may also be removed through the bronchoscope.

High tracheotomy, besides being called for in the case of foreign bodies below or obstruction above it (in the larynx), is not infrequently done as **a preliminary operation** in several operations about the mouth and neck. Its *object* is usually to prevent blood entering the trachea, and for this purpose the trachea is plugged around the tube by one of the several tampon cannulæ or by small pieces of sponge or gauze. The same object may be attained without tracheotomy by a low position of the head, hanging over the end of the table (Rose's position). In every tracheotomy a slight amount of blood enters the trachea when it is opened, but if it merely comes from a venous oozing the latter soon ceases when the air rushes into the lungs and the right heart is allowed to empty itself.

The real *surgical limit of the trachea* is the episternal notch; the thoracic part of the trachea is described among the contents of the thorax, as is also the entire esophagus.

The Thyroid Gland (Fig. 55).—Its **lateral lobes** *extend* from the fifth or sixth tracheal rings, 18 mm. (¾ in.) above the sternum, up to the middle of the thyroid cartilage. Their greatest *dimensions* are normally about 5 cm. (2 in.) in length, 3 cm. (1¼ in.) in breadth, and 18 mm. (¾ in.) in thickness. When the lobes distinctly exceed these measurements they may be considered to be *enlarged.* They may be temporarily enlarged in menstruation. In infancy and in females they are relatively larger than in adults and in males respectively, and the right lobe is also commonly larger than the left. It is also noticeable that thyroid enlargements (*goitre, bronchocele*) are more common in females and on the right side. The size of the gland commonly diminishes in late life.

The **isthmus** varies from 6 to 18 mm. (¼ to ¾ in.) in *height* and lies in front of the second, third, and fourth tracheal rings, but it may extend up to the cricoid and sometimes nearly down to the sternum. In infants it is but slightly developed, which is of advantage in tracheotomy. It is absent in 10 per cent. of cases. From its upper margin, or the adjacent margin of the left lobe, springs the *pyramidal lobe* when present, as it is in from 80 per cent. (Streckeisen) to 43 per cent. (Marshall) of cases. This represents a remnant of the median anlage of the thyroid, the thyroglossal duct, which in the fetus extends downward from the foramen cecum on the tongue in front of the hyoid bone. This duct occasionally remains open and gives rise to a fistula of the neck. From it are developed the aberrant or *accessory thyroids,* not infrequently found in the neighborhood of the hyoid bone and sometimes behind, in front or

even within the larynx or trachea. Other goitre nodules have become secondarily separated from the rest of the gland or goitre, to which they remain connected by connective-tissue bands. Such *false, aberrant, or accessory goitres* may cause difficulty in diagnosis and removal, as they are likely to become very movable, even slipping into the mediastinum. Deeply seated carcinoma of the neck may also have its origin in them.

The relations of the thyroid are of great importance in reference to the symptoms of its enlargement and the operation of excision or enucleation of such enlargements. It is covered **in front** by the sternohyoid, sternothyroid, and omohyoid muscles and overlapped by the anterior border of the sternomastoid. It lies beneath the superficial and middle layers of the deep cervical fascia. It is enclosed by a **fibrous capsule** from whose inner and upper parts two broad bands, the *suspensory ligaments*, are continued inward and upward, to be attached to the back of the cricoid cartilage. The expansion of the fibrous capsule from the isthmus to the cricoid cartilage is divided in tracheotomy to allow the downward retraction of the isthmus. This, the external fibrous capsule of Kocher, contains several veins—*venæ accessoriæ* (Kocher), also sensory nerves and muscle fibres and the recurrent laryngeal nerves. Hence this capsule should be opened and left behind in excision of the gland. The thyroid is moulded to the *underlying* trachea and larynx, and is attached to them by fibrous tissue, where it is in contact, as well as by the suspensory ligament. Hence it *moves with them in deglutition*, an important point in the diagnosis of bronchocele from other cervical tumors.

The **enlarged thyroid** may *compress the trachea*, especially if the enlargement is rapidly formed, for it is held down by the overlying muscles and the deep fascia which forms their sheaths. Hence to relieve the dyspnea the division of these muscles or of the isthmus has been practised, but often with unsatisfactory results. In chronic enlargement the pressure may cause erosion of the tracheal rings and collapse of the trachea. When the enlargement is unilateral the mobile trachea may escape pressure by being pushed to the opposite side. Those tumors cause the most marked pressure symptoms which, developed from the lower end of the gland or from an accessory gland, lie between the trachea and the sternum.

The thick **posterior border** is in contact with the *carotid sheath* and is grooved by the common carotid artery. A large goitre may press the great vessels outward, it may cause congestion of the face and head, with headache, vertigo, or epistaxis by pressure on the internal jugular, and, by adhering to the latter, it may add to the difficulties of excision. On account of its contact with the carotid the enlarged thyroid may receive pulsation from it; and if a unilateral thyroid tumor is soft and vascular the resemblance to aneurysm is still closer, especially when a thrill or bruit is produced, as may be the case. The pressure on the carotid and internal jugular may disturb the cerebral circulation. The thyroid is also in *contact with* the lower part of the *pharynx* and with the *esophagus*, especially on the left side, and when enlarged may cause dysphagia.

The relation to the **recurrent laryngeal nerves** is of the utmost importance, as pressure on them may lead to their paralysis and the resulting

alteration or loss of voice, and they are also in danger of being injured in excision of the thyroid. The left recurrent nerve is more exposed to pressure, for it lies more external to and less behind the trachea. The recurrent nerves are in danger of being injured in the *ligation* of the *inferior thyroid artery,* being most often found in front of or behind the two branches of this artery, near the point of bifurcation. Hence the artery is tied only once, carefully, and severed close to its entrance on the postero-inferior aspect of the gland. The *sympathetic nerve* is also in close relation to the trunk of this artery, usually embracing it, and the middle cervical ganglion is in contact with it. As the gland is supplied by branches from this ganglion the latter has been removed for the cure of exophthalmic goitre.

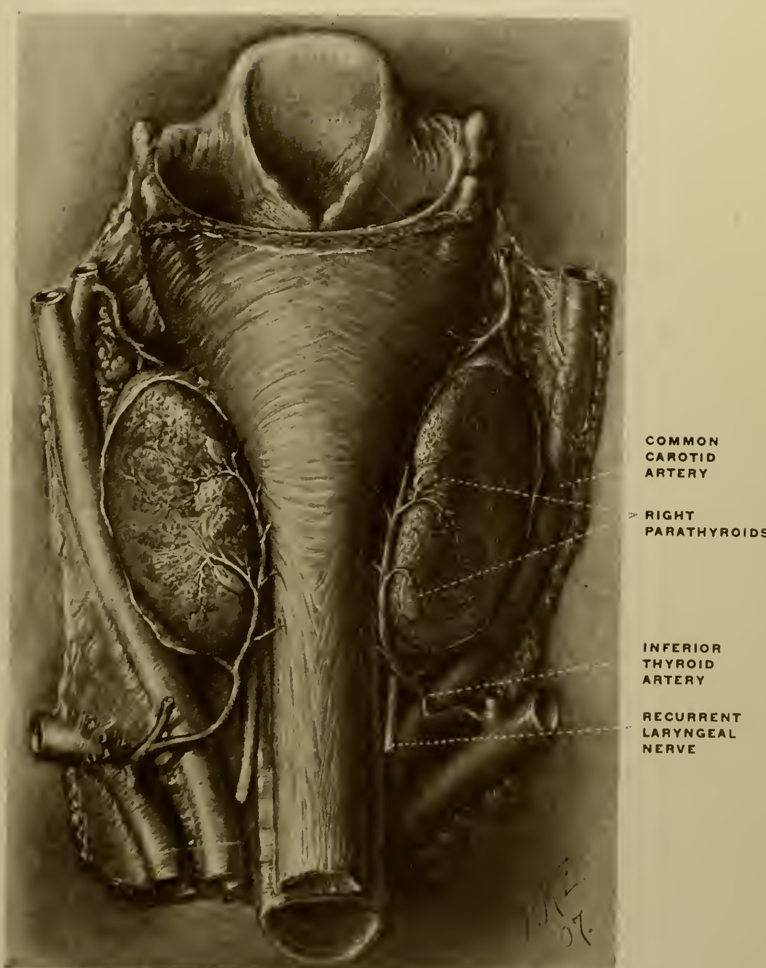
Relatively to the volume of the gland the **arteries,** *superior, inferior,* and, in the 10 per cent. when present, the *thyroidea ima,* are of large size, so that the gland is one of the *most vascular* of organs. There is but little arterial anastomosis between the two sides along the isthmus, but a branch to the pyramidal lobe from the superior thyroid may cross the upper end of the trachea and be in the way in tracheotomy. The *four arteries* are situated at the *four angles* or poles of the two lobes and run some little distance on the posterior surface before entering the gland. The *inferior thyroid artery* passes in front of the vertebral and behind the common carotid a little below the transverse process of the sixth cervical vertebra. It usually divides into two branches before entering the gland, about opposite the cricoid. There is usually a *venous anastomosis* just above and below the isthmus; the former is between the superior veins, the latter is the starting point for the inferior thyroid veins. The superior thyroid veins cross the external or common carotid, the inferior threaten the operator on either side of the wound in a low tracheotomy, and the middle cross the common carotid about where the omohyoid crosses it.

The function of this ductless gland, which has only an internal secretion, is still imperfectly understood. Apparently it depends upon the iodine-containing albumin (iodothyrin), which is capable of replacing the thyroid secretion. From the effects of the loss of the gland and of the use of gland extracts we know that functionally the thyroid assists in metabolism, regulating oxidization in the body, and has a special influence on (1) the nervous system, especially the sympathetic vasomotor nerves; (2) on the skin; (3) on the osseous system; and (4) on the sexual functions. Its atrophy, destruction, or complete removal, or the degenerated goitrous condition met with in cretins, is likely to lead to cachexia strumipriva or **myxedema,** a condition in which a mucinoid substance is deposited in the subcutaneous tissues, especially in the eyelids, lips, and hands. Hence the entire gland should never be removed for a simple goitre. One-fourth of the gland is enough to prevent the occurrence of myxedema. An atrophic or degenerated condition of the gland, occurring congenitally or before puberty, is apt to be followed by the interference with the physical and mental development and the general nutrition associated with "*cretinism.*"

The most important **pathological changes** involving the thyroid consist

PLATE X

FIG. 56



Parathyroid Glands. (Halsted and Evans.)

in an **enlargement** of a part or the whole of the gland, known as *goitre*, *bronchocele*, or struma. This hypertrophy may involve all the elements nearly equally, or either the parenchyma, the fibrous or vascular elements more especially. Thus we may have soft parenchymatous goitres, often with one or more cysts from enlarged vesicles, hard fibrous goitres, and again soft vascular goitres. The latter are associated with exophthalmos and tachycardia in **exophthalmic goitre**. The relation of the middle cervical sympathetic ganglion and its vasomotor fibers to the inferior thyroid vessels and of other cervical sympathetic fibers to the eye and the heart may perhaps explain some of the phenomena of this form. For this reason removal of the cervical sympathetic has been advocated. Adenomatous and, more rarely, cancerous goitres also occur. For goitres, especially when they cause disturbance from pressure, *excision*, *enucleating excision*, or *enucleation* is done. One side only is usually operated on in excision, but in the latter two forms of operation, where part of the gland is left, both sides may be dealt with.

In Kocher's method of **excision** a transverse "collar" incision is made, curved somewhat downward, from one sternomastoid muscle to the opposite one. *After dividing* the skin, subcutaneous tissue, platysma, anterior jugular veins, etc., flaps containing these structures are turned up and down. Then incising the superficial and middle layers of the cervical fascia in the median line between the infrahyoid muscles, the sternohyoid and sternothyroid muscles are retracted and may be partly, or wholly, divided at their upper ends. The external *capsule* of the gland is then opened and stripped back by blunt dissection after securing the accessory veins in its outer surface. The tumor or gland lobe is then delivered out of its bed in a forward and inward direction by blunt dissection. Then the superior vessels are cut between two ligatures at the upper pole, the inferior thyroid artery cautiously ligated, and its branches cut where they enter the gland, the inferior thyroid veins cut between two ligatures, the isthmus divided after being crushed and ligated, and the gland separated from the trachea. To avoid injury of the recurrent laryngeal nerve or removal of the parathyroids the postero-internal part of the capsule with a little gland tissue should be left. This constitutes the enucleating excision.

The Parathyroid Glands.—The parathyroid glands are small, reddish-brown, kidney-shaped, ductless organs averaging 6 to 7 mm. ($\frac{1}{4}$ in.) in their long diameter, always enclosed within their own capsule, and generally situated on or near the posterior border of the lateral lobes of the thyroid gland. They vary from one to five in number, averaging about three, and four is the usual number, with a superior and an inferior gland on either side. The superior are generally on a level with the lower border of the cricoid cartilage, the inferior within 1 cm. of the lower end of the thyroid, sometimes below it, and almost always below the inferior thyroid artery.

They are always supplied by a special parathyroid artery, the inferior always and the superior usually from a branch of the inferior thyroid artery or the anastomotic "channel," present in about 50 per cent. of

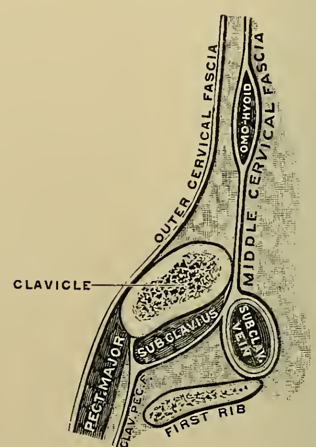
cases, between the inferior and superior thyroid arteries, on the posterior surface near the mesial border. At times the inferior thyroid arteries anastomose across the isthmus, or the parathyroid artery may anastomose with esophageal arteries.

The function is very distinct from that of the thyroid. Removal of all the parathyroids or the destruction of their blood supply causes death from acute tetany. As the loss of their blood supply is the most frequent cause of tetany, great care should be observed in thyroidectomy only to tie the arteries that actually enter the thyroid, and hence also the importance of the anastomoses mentioned above. Kocher advises against

Fig. 57

Sagittal section of the cervical fascia between the hyoid and sternum. (Gerrish, after Testut.)

Fig. 58



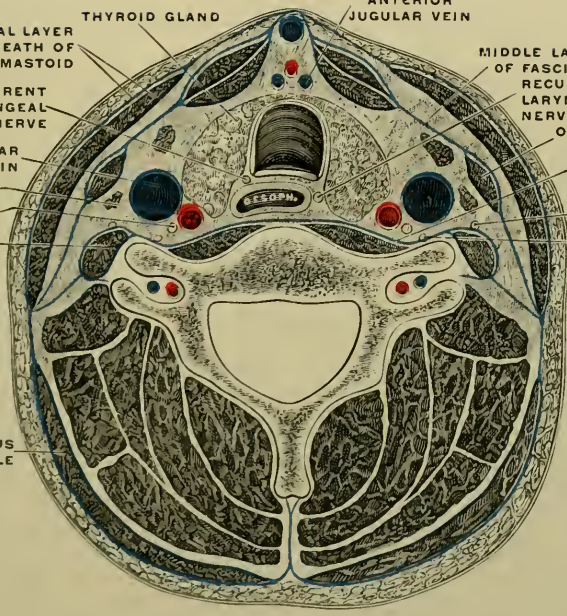
Sagittal section of the cervical fascia in the clavicular region. (Gerrish, after Testut.)

tying two main arteries at one sitting. The parathyroids may themselves be spared by leaving the posterior part of the capsule, with perhaps a thin layer of thyroid tissue. In a considerable number of thyroidectomies I have never seen tetany. The posterior part of the capsule has been left, but no special precautions taken in tying the arteries, save to avoid the recurrent nerve. Injury to the parathyroid or its blood supply is especially serious when only one or two are present and on the side of operation only.

The Deep Cervical Fascia (Figs. 57, 58, and 59).—The deep cervical fascia is of considerable surgical importance, but its description differs with almost every writer on the subject, owing in part to the individual

PLATE XI

FIG. 59



Transverse Section of the Neck through the Sixth Cervical Vertebra, to show the layers of the deep cervical fascia and their relations. Lower segment of the section. (Tillaux.)

differences met with in almost every case. In general, three layers may be described below the hyoid bone. The **superficial layer** splits to enclose the sternomastoid and trapezius muscles in a sheath. This layer on the two sides unites anteriorly in the median line and posteriorly with the ligamentum nuchæ, thus forming a complete investment of the neck. *Below* it is *attached* to the sternum, clavicle, the acromion, and the spinous process of the scapula. In the *anterior median line,* below the thyroid gland, this layer *splits* into *two divisions* attached to the anterior and posterior borders of the episternal notch. Between these two divisions is a triangular space, continuous with the space between the two layers of the sheath of the sternal head of the sternomastoid, and containing cellular and adipose tissue and one or two small lymph nodes (Paulet). *Above the hyoid bone* it splits to form a *sheath* for the *submaxillary gland* which is attached to the lower border of the jaw. Above this it is continuous with the *parotid* and *masseteric fasciae.* From the anterior border of the sternomastoid sheath a thickening passes forward to the angle of the jaw and is continued to the styloid process as the *stylomandibular ligament,* which separates the sheath of the submaxillary from that of the parotid gland. This ligament is important in checking overaction of the external pterygoid.

The middle layer is attached to the hyoid bone, covers the muscles above it which form the floor of the submaxillary triangle, and is attached to the mylohyoid ridge. Below the hyoid it forms a *sheath* for the sternohyoid, sternothyroid, and omohyoid muscles. In the *median line,* in the interval between these muscles, the fascia of the two sides joins together and with the superficial layer, forming a kind of *linea alba* of the neck in the line of median incision. *Laterally* this layer is said by some to reach only as far as the limit of the omohyoid, which it ensheathes, and by others to join the superficial layer near the posterior border of the sternomastoid. *Inferiorly* it is continued down into the mediastinum, sending an expansion around the left brachiocephalic vein, which is continuous with the fibrous layer of the *pericardium.* More laterally it is attached to the posterosuperior border of the clavicle, whence it sends an expansion around the great veins behind it (subclavian and internal jugular). Thence it passes to the sheath of the subclavius muscle, and from the latter is continuous with the *clavipectoral fascia* (costocoracoid membrane).

From the *deep surface* of this layer are given off cellular *expansions* which surround in a sheath-like manner the *trachea, thyroid body,* and *carotid vessels,* but do not deserve the name of fasciæ, although sometimes a distinct "pretracheal layer" is described. The "*suspensory ligament*" of the thyroid gland, attaching it to the cricoid cartilage, is derived from this expansion. According to Merkel, the *carotid sheath* is made up of loose connective tissue and does not deserve the name of sheath. The attachment of this layer of fascia above and the diaphragm below to the pericardium helps to keep the latter so stretched as to prevent any pressure of the lungs upon the heart (Hilton).

The **deep or prevertebral layer** covers the prevertebral muscles and is

attached *laterally* to the cervical transverse processes, where it is continuous with the sheath of the scalenus anticus muscle and of the brachial plexus. Thence it passes outward to join the superficial layer. *Inferiorly* it is continuous with the sheath of the subclavian and axillary vessels. According to some it completes the carotid sheath posteriorly. It lies behind the esophagus and pharynx.

The occipital, superior carotid, and submaxillary triangles are roofed over by the superficial layer; the subclavian and inferior carotid triangles by the superficial and middle layers. The layers as thus described bound certain *spaces* and the great practical importance of this fascia consists in its tendency to *limit* the growth of cervical *tumors* and the course of cervical *abscesses*. This limitation is by no means absolute, for abscesses often break through fascial planes. Cold abscesses are more likely to be guided by fascial planes than those due to acute inflammation.

Between the *superficial fascia* and the *superficial layer* of the deep fascia lie the external jugular vein, the platysma and loose tissue. **Abscess** here perforates externally and so does one between the superficial and middle layers, as the superficial layer is generally thin and offers little resistance to pus. Hence there is little tendency for abscess between the superficial and middle layer to descend into the mediastinum, and it is prevented from descending into the axilla by the attachment of the middle layer to the clavicle. Suppuration is more common here than elsewhere in the neck. This compartment contains the anterior jugular veins, loose connective tissue, and lymphatic nodes.

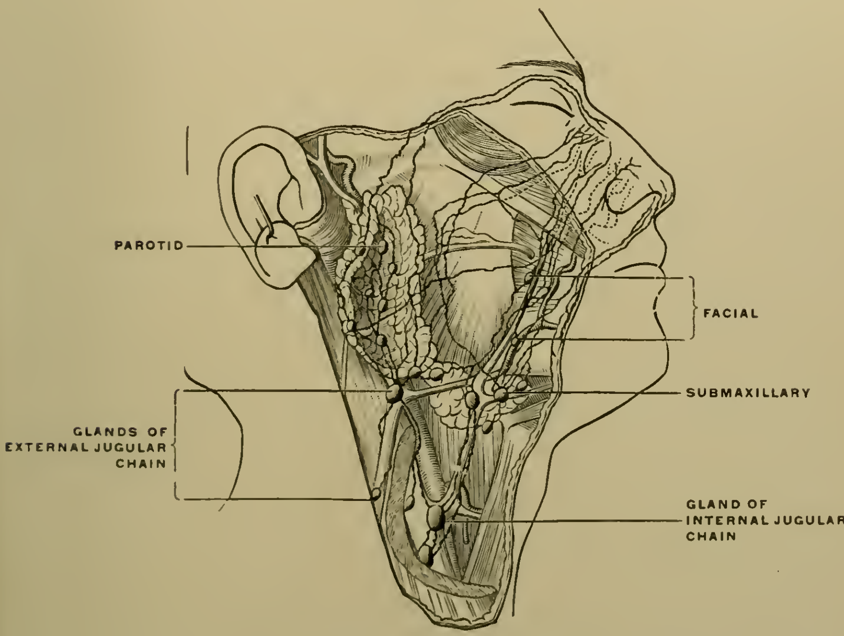
Abscess in the **third compartment**, that between the middle and deep layers, cannot reach the surface without perforating the two overlying layers, hence unless promptly relieved it is likely to *extend* down into the *mediastinum or axilla,* with which this space is continuous, depending for its course upon whether the abscess is situated mesially or laterally. Mesially it follows the loose tissue around the trachea and esophagus, as after operations on the base of the tongue, the larynx, trachea, thyroid, or esophagus. As *this compartment* also *contains* the most *important structures* of the neck, the trachea, esophagus, thyroid gland, carotid artery, and the accompanying vein, nerves, and lymph nodes, an abscess may exert a *serious pressure* upon these structures. For these two reasons an *early incision* in such deep abscesses of the neck is imperative. Owing to the lack of it such abscesses have burst into the trachea or esophagus and even into the pleura. Occasionally they have opened into the great vessels, as in a remarkable case reported by Mr. Sarony, where a considerable part of the common carotid, a still larger part of the internal jugular vein, and a large part of the vagus nerve were destroyed (Treves). Such cases depend upon the unyielding character of the cervical fascia. The communication between abscesses and large deep vessels have usually taken place beneath the cervical fascia or the fascia lata (Jacobson).

In the *fourth compartment* an *abscess* is known as *prevertebral* or *retropharyngeal,* if above the lower limit of the pharynx. The latter form may be *opened* through the mouth or from the side of the neck, and if unrelieved

may gravitate down into the mediastinum. *Laterally* these deep abscesses may follow the brachial plexus to the posterior triangle or even to the axilla. The retropharyngeal abscesses arising from infected lymph nodes are in front of the prevertebral fascia, behind the pharynx. In general, then, superficial abscesses, or those external to the middle layer, are comparatively safe, showing a tendency to perforate and open externally; *deep abscesses*, or those *beneath the middle layer*, are *dangerous* from pressure or the liability to extend into the mediastinum, and should be relieved by *incision* as *promptly* as possible.

As the cervical fascia gives a sheath to the large veins that perforate it and are in contact with it and attaches them closely to the adjacent

Fig. 60



The lymphatics of the neck. (Küttner.)

bones and muscles, they are thereby held patent and ready for the free flow of blood from the head and neck, and at the same time they are more liable to gape when wounded, so as to admit air. Hence they should always be ligated before division. According to some the cervical fascia, by reason of its firmness and its attachment to bones above and below, supports the soft parts of the neck, especially the veins, and helps them to *resist atmospheric pressure* in inspiration, as first pointed out by Allan Burns.

The Lymphatic Nodes (Fig. 60).—The lymphatic nodes of the neck receive the *lymphatics* of the *head and face*, and are liable to become *enlarged* in the course of the various septic, tuberculous, syphilitic, and cancerous affections of the parts from which their lymphatics come.

Among enlarged lymph nodes of the neck *lymphadenoma* of tuberculous origin is a very common condition, and forms the majority of tumors of the neck, the source of infection being usually the upper air passages (nose, nasopharynx, pharynx, and tonsils). The breaking down of enlarged cervical nodes is a common cause of abscess of the neck. It follows that it is important to have a clear idea of the sources from which the several groups of nodes are supplied both to aid in the diagnosis of the primary lesion and in order to know where to look for lymphatic involvement in any given lesion.

The **suboccipital nodes**, just below the posterior attachment of the occipitofrontalis and just lateral to the trapezius, receive lymph from the back part of the scalp, and are frequently enlarged in secondary syphilitic eruptions of this part. The **mastoid nodes**, just over the insertion of the sternomastoid, and the **parotid nodes**, on and in the parotid gland, receive the lymph from the middle and anterior part of the scalp respectively. The parotid nodes also receive lymphatics from the eyelids, the root of the nose, the external surface of the auricle, the external auditory canal, and the tympanum. For the postpharyngeal nodes see p. 127. The five or six **submaxillary nodes**, under the sheath of the submaxillary gland in the digastric triangle, form a chain along the lower border of the jaw. Their tributaries come from the upper lip and lateral part of the lower lip, the forepart of the lateral border of the tongue, the nose, cheek, and gums. The one to four **submental nodes**, on the mylohyoid and between the anterior bellies of the digastric, receive lymphatics from the middle of the lower lip and chin, the tip of the tongue, and the floor of the mouth.

Facial Nodes.—These consist of three groups of small glands along the course of the facial vessels. They are traversed by the afferent vessels of the submaxillary nodes. They are found on the surface of the jaw, in front of the masseter, on the outer surface of the buccinator, etc.

The *subparotid* nodes lie between the parotid and the pharynx in contact with the great vessels. They receive afferents from the nasal fossæ, nasopharynx, and Eustachian tubes, and may be the starting point of a lateral pharyngeal abscess.

The above nodes empty into the **deep cervical nodes** which accompany the internal jugular vein to its lower end. They are arranged in *two sets,* an *external or posterior chain* near the posterior border of the sternomastoid and an *internal chain* on or just external to the internal jugular. The former comprises smaller and fewer nodes whose afferents come from the posterior part of the head and neck. All the nodes are beneath the sternomastoid and the deep layer of its sheath. They are largest and most numerous above and may lie entirely above the point where the omohyoid crosses the vein. Just above this point there is always a fair-sized node, there are also one or two large ones just beneath the posterior belly of the digastric, which are the chief terminus of the lymphatics of the tongue. At the base of the neck the efferents communicate with those of the subclavian and axillary nodes, to form a common trunk. In addition to the deep cervical chains three or four accessory chains may be distinguished:

1. *The external jugular chain* comprises two to five nodes along the upper part of the external jugular vein, on the outer surface of the sternomastoid, with sometimes one or two nodes below.

2. *The superficial anterior cervical chain* along the anterior jugular vein comprises two or three inconstant nodes.

3. *The anterior deep cervical chain* are composed of two or three groups of small inconstant nodes in front of the larynx, thyroid gland, and trachea.

4. *The recurrent chain* consists of a few small nodes along the recurrent laryngeal nerve.

As the nodes in the subclavian triangle communicate directly with the axillary nodes, they may become involved in carcinoma of the breast, but as they receive no vessels from the mediastinal glands their involvement following gastric carcinoma can only be explained by a retrograde thrombosis of their efferent vessels. Such involvement is very unusual.

In most cases where the nodes are exposed by operation many more are involved than expected, and a chain of glands, gradually decreasing in size, leads downward from the position of the visible tumor. Therefore, in *removing* cervical *lymphadenoma* the *operation* often proves more extensive and formidable than expected. They may be considerably enlarged without detection by palpation, and we often feel them without suspecting their real size or numbers. In removing them their *relation* to the *internal jugular vein* is of great importance, as they may be adherent to it and difficult to separate from it, especially when involved secondarily to cancer. In such cases the vein and surrounding lymph-bearing tissue should be removed without hesitation. With the exception of a few, like the external jugular chain, the cervical lymph nodes lie beneath the deep fascia. They may also be enlarged in the rare cases of *lymphosarcoma* and in the peculiar affection known as *Hodgkin's disease.* Although in most cases of involvement of the lymph nodes the infection comes from the same side of the body as the enlargement, yet in exceptional cases it comes from the opposite side. Thus exceptionally when one side of the tongue is the seat of epithelioma the opposite submaxillary nodes are involved.

Embryology.—Embryologically the neck is formed by the coalescence of five visceral **arches** separated by four furrows or **clefts**. These furrows, seen on the surface, correspond to a like number of *inner clefts* or pharyngeal pouches on the walls of the pharynx, separated from the outer clefts by a thin *occluding membrane,* composed of a layer of entoderm and one of ectoderm. Of these arches and clefts the **first arch** becomes differentiated into a maxillary and a mandibular process, which *form* the upper and lower jaws, the incus and the malleus; the **second arch** contributes the stapes, the styloid process, the stylohyoid ligament, and the lesser cornu of the hyoid bone; the **third** forms the body and great cornu of the hyoid; the fourth and fifth arches, the second and third branchial in man, form no special structures, but soon blend with surrounding structures and lose their identity. The **first outer cleft** forms the external ear, the corresponding **inner cleft** the middle ear and Eustachian tube, and the **closing membrane** between them forms the membrana tympani. The second

pharyngeal pouch is probably represented by the fossa of Rosenmüller. The *fourth inner cleft* contributes to the formation of the thyroid gland, and the tissues of the ventral ends of the *second* branchial arches take part in forming the posterior third of the tongue and most of the thyroid gland, through the thyroglossal duct.

If the lower or branchial arches do not fuse together, as they normally should in the second month of fetal life, the corresponding cleft remains partly open as a so-called **branchial fistula**. These may be complete or incomplete. In the case of *complete fistulæ* the closing membrane gives way and there is a narrow canal lined by mucous membrane, leading from without backward, inward, and upward for 3.5 to 6.5 cm. ($1\frac{1}{2}$ to $2\frac{1}{2}$ in.). The *internal opening* of such a fistula is usually near Rosenmüller's fossa, the tonsillar sinus, or the pyriform sinus of the larynx. The *external opening* varies in position according to the cleft which remains open, being most often near the sternoclavicular joint, in the region of the fourth cleft, or at the anterior or posterior border of the sternomastoid near the level of the larynx, in the second or third cleft. *Incomplete fistulæ* open either externally or internally in the same position as one end of a complete fistula. Near the external opening of a fistula, or in spots where they commonly open, a protruding fold of skin may be found, and above it a cartilaginous mass is sometimes to be felt. As the external ear is formed by the fusion of six similar nodules at the outer end of the first visceral cleft, the more prominent of these are called *cervical auricles*. Median fistulæ of the neck, or tracheal fistulæ, are rare, and, if incomplete and internal, may give rise to tumors filled with air.

From obstruction of the external or internal opening of a fistula or from a portion of the wall of the cleft shut in by the closure of the arches, dermoid and **branchiogenic cysts** may be formed. Such shut-in portions of epithelial tissue may be the nucleus of the rare primary carcinomata of the neck.

CHAPTER II.

THE UPPER EXTREMITY.

The upper extremity, *the organ of prehension and touch*, is *notable for its mobility*, which is due to the freedom of movement of its joints and its many muscles. Its only bony connection with the skeleton of the trunk is through the clavicle.

In the upright position the upper extremity reaches to the middle of the thigh, the right being stronger and $\frac{1}{2}$ to 1 cm. ($\frac{1}{5}$ to $\frac{2}{5}$ in.) longer, as a rule. The greater development of the right upper extremity depends, according to Hyrtl, on the arrangement of the blood supply which on the right side, is more abundant and comes more directly from the heart. The anomalous origin of the right subclavian as the last branch of the aortic arch is associated, according to the same author, with left-handedness and the greater development of that side.

THE REGION OF THE SHOULDER.

This comprises the upper part of the extremity and reaches down to the insertion of the pectoralis major and latissimus dorsi muscles.

Surface Landmarks and Markings.—The clavicle, acromion process, spine, vertebral border, and angle of the scapula can be readily *felt subcutaneously*. The **clavicle** is not quite horizontal, but in robust muscular persons and in the emphysematous it inclines slightly upward at its outer end in the erect position, and even more so in the reclining position when the weight of the arm no longer pulls it down. On the other hand, in narrow-chested, feeble, and consumptive persons the outer ends of the clavicles incline downward, causing the long necks and narrow sloping shoulders seen in such persons. The *upper surface* is only covered by skin and platysma and the anterior and posterior surfaces are also more or less readily palpable. The *deltoid tubercle* of this bone may be felt if large, and may even be mistaken for an exostosis. The curves of the bone are apt to be exaggerated in muscular persons. The *sternal end* is large and prominent, especially in muscular subjects, and the outer or *acromial end* is often enlarged and commonly projects above the level of the acromion, so that it should not be mistaken for a dislocation at the acromioclavicular joint. The latter joint is in the sagittal plane, passing up the middle of the arm anteriorly. The easiest way of determining shortening of the clavicle, in fracture or dislocation of that bone, is by measurement from the outer edge of the acromion to the suprasternal notch. The angular prominence which can be felt externally at the

junction of the **acromion** and the spine of the scapula is the best point from which to *measure the arm* down to the external condyle. The latter point, the tip of the acromion, and the radial styloid process are all in the same line when the arm hangs at the side and the palm looks forward.

When the arm hangs at the side the *upper angle* of the **scapula** corresponds to the upper border of the second rib, the *lower angle* to the seventh intercostal space. Hence the latter is a guide in selecting a space for aspiration or drainage of the chest in empyema, etc. The *vertebral end* of the *spine of the scapula* is opposite to the third thoracic spine, and to the fissure between the upper and lower lobes of the lung.

The *vertebral border* of the scapula may be made prominent for examination by carrying the hand as far as possible over the opposite shoulder, the *axillary border* and inferior angle by placing the forearm behind the back. The vertebral borders are parallel with the line of the thoracic spines when the arms hang at the side. When the arms are crossed on the front of the chest these borders are widely separated, hence this position is employed for auscultation and percussion.

The *prominence of the shoulder* is due to the acromion process, but the *roundness* just below this depends upon the prominent great tuberosity of the humerus covered by the deltoid muscle. Hence this roundness gives way to a flattening when the underlying bony bolster is removed, as in a dislocation of the shoulder, or is diminished in bulk, as in an impacted fracture of the anatomical neck. The **head of the humerus** can be felt high up in the axilla, especially when the arm is abducted, which brings the head in contact with the lower part of the joint capsule. The lower margin of the *glenoid cavity* can also be felt high up in the axilla below the humeral head. The *head* and *internal condyle* of the humerus and the styloid process of the ulna are in the *same line.* This relation of the head and internal condyle, being constant in all positions of the arm, is of value in the diagnosis of injuries about the shoulder and in reducing dislocations, by enabling us to determine the position in which the head should be from the position of the internal condyle. In thin subjects the two *tuberosities* of the humerus and the *bicipital groove* between them can be felt beneath the deltoid, especially on rotating the humerus. The bicipital groove looks directly forward when the arm hangs at the side with the palm of the hand looking forward.

The groove between the deltoid and pectoralis major, distinguishable in most cases, contains the *cephalic vein* and, more deeply, the humeral branch of the acromiothoracic artery. The upper end of this groove widens out into a triangular *infraclavicular fossa*, the base of the triangle being formed by the clavicle. On deep pressure here the *coracoid process* can be felt just beneath the margin of the deltoid and a little below the clavicle. The depression of the infraclavicular fossa is obliterated in subcoracoid dislocations of the humerus, in some fractures of the clavicle with displacement, in some axillary tumors, in lymphatic enlargements and in inflammations along the upper part of the axillary artery. It is replaced by a prominence in intracoracoid dislocations of the humerus. If the muscles are relaxed we may detect the pulsation of the *axillary*

artery by pressure in the infraclavicular fossa below the middle of the clavicle just to the inner side of the coracoid process, and we may also compress the artery against the second rib. By a vertical incision through the centre of the *coraco-acromial ligament* the shoulder joint is opened and the biceps tendon is encountered. Hence in resection of the shoulder joint the coracoid process is a landmark for the incision.

The *anterior border of the axilla* is formed by the *lower margin* of the *great pectoral muscle* which passes from the sixth costal cartilage to the outer bicipital ridge and nearly follows the line of the fifth rib. The anterior and posterior axillary borders are well-marked, especially when the arm is abducted to an angle of about 45 degrees and the muscles forming these borders are contracted, in which position the *depression of the axilla* is deepest. As the arm is raised to and above the horizontal line, the axillary depression becomes shallower by reason of the projection into it of the humeral head, the approximation of the anterior and posterior axillary folds, and the projection of the coracobrachialis muscle along the humeral side of the axilla. When the arm is brought nearly to the side the thoracic wall bounding the axilla internally can be explored as high up as the third rib. The *axillary lymph nodes* on this or on the outer side cannot be felt unless they are enlarged.

Topography of Some of the Deeper Parts.—When the arm is abducted the **course of the axillary artery** is represented by a line from the centre of the clavicle to the groove along the inner border of the *coracobrachialis muscle*. The latter muscle comes well into view when the humerus is rotated a little outward.

The position of the *pectoralis minor* muscle is outlined by two lines converging from the upper border of the third and the lower border of the fifth rib, just external to their cartilages, to the coracoid process. The position of the *acromiothoracic artery* is indicated by the point where the upper line crosses the course of the axillary artery and the *long thoracic artery* runs in the lower line. When the arm hangs at the side the *circumflex nerve* and *posterior circumflex artery* wind around the humerus under the deltoid about a finger's breadth above the centre of the vertical axis of this muscle. At the latter point the dorsalis scapulæ artery crosses the axillary border of the scapula (Treves).

For convenience of study we may divide the shoulder into four regions: (1) the anterior or clavicular region; (2) the posterior or scapular region; (3) the outer or deltoid region (including the shoulder joint); and (4) the axilla.

The Anterior Region of the Shoulder.

This is also called the **clavicular region** because the **clavicle** forms its bony framework. **The skin** over this region is loosely attached and, hence, freely movable, a fact which explains why it usually escapes being wounded in contusions and partly accounts for the rare occurrence of compounding in fractures of the clavicle. The **supraclavicular nerves**, the cutaneous nerves of this region, in their passage in front of the middle

third of the clavicle are liable to contusion, and such an injury explains the occasional severe pain after blows on the clavicle. According to Tillaux, the severe pain which occasionally persists after fractures of the clavicle is due to the involvement of these nerves in the callus.

Fracture of the clavicle is one of the commonest forms of fracture, a fact due to its superficial position, its slender form, and the circumstance that it receives a large share of almost all shocks which involve the upper extremity. Such fractures are more often due to indirect than to direct violence. The great majority of the **indirect fractures** are at the *outer end of the middle third* (*i. e.*, the middle 5 cm. (2 in.) of the bone, for the reason that this is the most slender and most sharply curved part and also the meeting point of the two curves and of the more fixed outer third with the more movable inner two-thirds. In this connection it may be noted that the clavicle breaks in such cases by the exaggeration of its normal curves.

The **direction** of the fracture is accordingly usually obliquely inward, downward, and backward. As to the **displacement** that occurs, it should be borne in mind that as the outer third of the clavicle is firmly attached to the scapula, its displacement, after fracture internal to it, will be determined by the change in position of the scapula; also that the clavicle serves as a kind of outrigger to hold the shoulder and upper extremity away from the thorax. When this support is broken the shoulder with the outer fragment is naturally displaced inward and sinks downward by its own weight. The inward displacement also causes the shoulder to *swing forward* so that the common displacement of the inner end of the *outer fragment is downward, inward, and forward.* The outer end of the outer fragment is also *rotated forward.* This outrigger action of the clavicle may be illustrated by a bar supporting a sign from a building, the outer end of the bar being also supported by a chain from a point higher up on the wall, the chain representing the trapezius, etc. If the bar breaks the outer end with the sign falls downward and inward. But this is not the only and perhaps not the most important *cause of the displacement,* the other causes being the continuance of the force producing the fracture, the direction of the fracture, and the action of the muscles. Thus in transverse fractures there may be no such displacement, but instead of it an angular one with the apex upward and backward, due to the sinking of the shoulder downward and forward, or there may be no displacement at all, especially in green-stick fractures. Again, if the oblique direction is much inclined inward and backward, the inner end of the outer fragment may be forced behind or simply below the inner fragment and not in front of it. Among the *muscles* the *pectorals* and *latissimus dorsi* pull the outer fragment inward and downward. The outer end of the outer fragment is rotated forward by the pectorals and the serratus magnus. The *inner fragment,* if displaced at all, is pushed up by the outer fragment beneath it, rather than pulled up by the sternomastoid, for the action of the latter is resisted by the rhomboid ligament, the upper and inner fibers of the pectoralis major, and by the subclavius.

Owing to the inward displacement of the outer fragment causing the fragments to overlap, there is necessarily a considerable *shortening* which may nearly equal, in extreme cases, one-third the length of the bone, or 5 cm. (2 in.). As this shortening is difficult to remedy completely, it follows that some shortening remains permanently after fracture of the clavicle more often than after any other fracture save that of the femur. This shortening causes some narrowing and rounding of the affected shoulder.

It follows from the nature of the displacement that **reduction** is to be obtained and maintained by carrying the shoulder upward, outward, and backward. Upward pressure on the elbow carries the shoulder upward, and, with a pad in the axilla as a fulcrum and the arm as a lever, inward pressure at the elbow forces the shoulder outward. But if the pad is large enough to be of much use, it may be dangerous from its pressure on the vessels and nerves, and if it is small enough to avoid these dangers, it is useless. Some shortening and *deformity* usually *persists*, and any forward displacement of the outer fragment may be particularly hard to keep reduced unless the patient is willing to lie perfectly flat on the back with the head slightly elevated for three weeks or so. In this *recumbent position* the weight of the arm no longer drags the shoulder downward, and the weight of the shoulder and the pressure of the body on the vertebral half of the scapula, forcing its outer border outward and backward, pull the outer fragment outward and backward, and correct its forward rotation and displacement better than any form of bandage. The mobility of the clavicle and the number of strong muscles attached to it explain the difficulty of applying a satisfactory fixed dressing and the tendency of the callus to become excessive. In *fracture* of the **outer third**, the next most common variety, which is more often transverse than oblique, there may be *no displacement or an angular one*, directed backward, due to the forward and inward turning of the outer fragment.

The clavicle may be **broken by muscular violence**, probably by the clavicular fibers of the *pectoralis major* and *deltoid*. These tend to draw the clavicle downward and forward, in which position the outer fragment is displaced in such cases. These fractures are most often in the *middle third*. Violent movements of the limb forward and inward or upward appear to be the commonest cause. Occasionally the fracture is due to a sudden depression of the arm, by which the clavicle is bent over the first rib. Fractures by **direct violence** are most apt to be *transverse* and may occur at any point, but most frequently at the *middle or outer third*.

Green-stick fracture, or fracture without rupture of the periosteum, and hence without much displacement, occurs more often in the clavicle than in any other bone. This is partly due to the fact that such fractures occur in childhood, and more than half the fractures of the clavicle are said to occur before the age of five. According to Krönlein fracture of the clavicle in children takes the place of dislocation of the shoulder by direct violence in later life. The *periosteum* at this age is also very *thick* and *loosely attached*. Notwithstanding the absence of marked deformity

and of much disability, and the failure of diagnosis that may result, the callus is often excessive, owing to the stripping up of the active periosteum.

The *firmness of the periosteum,* the common situation of the fracture, external to the middle of the bone and to the region of danger, but especially the presence beneath the clavicle of the *subclavius muscle,* enveloped in a dense fascia, are largely accountable for the *rare occurrence* of the **complications** of fractures of the clavicle, which consist of injuries to the vessels, nerves, and lung. Although the vessels and nerves lie beneath the clavicle in the angular interval between it and the first rib in the following order from within out, subclavian vein, artery, and brachial plexus, *injury to the artery* is not recorded, unless of such a nature as to produce subsequent aneurysm, and only a few cases of injury to the vein and brachial plexus are on record in fractures of the clavicle. The *vein* from its position, as the most internal of these structures in the acute angle between the clavicle and the first rib, and from its slighter resistance is likely to be the first to be compressed. Injury to the *internal jugular vein,* lying behind the clavicle, has also been recorded. *Injury to the lung* by a fragment of the clavicle, as evidenced by *emphysema,* has been observed in a few cases, and in other cases the emphysema was apparently due to a wound of the soft parts.

The *subclavius muscle,* interposed as a pad between the vessels and nerves and the clavicle, is of great service in **resection** of the latter, rendering the operation easy in the outer two-thirds, while *behind the sternal third* are the innominate or left carotid artery, the brachiocephalic and internal jugular veins, the vagus, recurrent, and phrenic nerves, the thoracic duct and the trachea. A little *more externally* the external jugular vein, the suprascapular vessels and the apex of the lung lie *behind the clavicle.* In case of *enlargement* of the clavicle from tumor (sarcoma), the resection of its inner third may be a matter of considerable difficulty, though in case of necrosis with thickening of the periosteum the operation is rendered much easier and safer, if it can be done *subperiosteally.* The *restoration of the clavicle* after subperiosteal resection is sometimes very complete, but even when no new bone forms the removal of the entire clavicle is followed by far less alteration in position and impairment of motion of the shoulder than would be expected from its function as a support and outrigger for the shoulder. The same is true in the occasional congenital absence of the clavicles or of their acromial ends and in the arrest of their development from epiphyseal separation. So striking is this in some cases as to lead one to question whether the displacement in fracture of the clavicle is not mostly due to the other factors, *i. e.,* continuation of the force producing the fracture, muscular action, and the direction of the fracture.

Avulsion of the entire upper extremity has occurred in a number of cases, especially in machinery accidents. Apart from the sternoclavicular articulation only muscles hold the upper extremity to the trunk, and if the clavicle is fractured only the rupture of muscles, vessels, and nerves is necessary in avulsion.

The Sternoclavicular Joint.—The lack of adaptability between the bony surfaces forming this joint accounts largely for the amount of motion that occurs here. When the arm hangs at the side the clavicle is in contact with the socket only at its lower angle, rendering the cavity V-shaped. This allows the elevation of the shoulder, in which position the bones are in more immediate contact. Accordingly in disease of this joint the motion of elevation of the shoulder is that which produces the most pain.

Dislocation of the clavicle from the sternum is *rare* on account of the strength of the ligaments that bind them together, which are stronger than the clavicle, and on account of the diffusion of the violence by means of the mobility of the scapula and the elasticity of the clavicle. Hence any violence which threatens the joint usually fractures the bone. The dislocation may be *complete* or *incomplete* and occurs in the (1) forward, (2) backward, and (3) upward directions, in the order of frequency. The relative frequency of these three varieties depends upon the relative strength of the ligaments that resist them and that restrict the movements of the joint. Thus, **dislocation forward** is *resisted* by the posterior and anterior ligaments, and the weakness of the latter serves partly to explain the relative frequency of the forward dislocation. The head of the bone, *displaced* forward and usually inward and downward, *rests on* the manubrium and carries with it the sternomastoid muscle. It is due to forcing the outer end of the clavicle backward. In this movement the first rib may form a fulcrum about which the inner end of the clavicle is carried forward.

Dislocation backward is *resisted* by the same ligaments and in addition the strong rhomboid ligament. It may be due to direct or indirect violence, more often the latter, the force pressing the shoulder forward and inward, as where a person is caught between two bodies. The *head* of the bone, *lying* behind the sternum and probably between it and the sternothyroid muscle, frequently *presses* upon the trachea, causing dyspnea, less often upon the esophagus, causing dysphagia. In the region occupied by the displaced head of the bone are most important vessels and nerves, especially the internal jugular and innominate veins, but the cases recorded show no serious pressure upon them. The head of the bone has been excised in one case to relieve troublesome dysphagia. In *complete dislocations* either forward or backward the head of the clavicle is usually also *displaced* downward, and in all complete dislocations it is, as a rule, displaced inward also.

In addition to the ligaments resisting backward dislocation, **dislocation upward** is *resisted* by the interclavicular ligament and the interarticular cartilage; hence, the rarity of this form, which implies a tearing of all the ligaments. It is usually *due to* forcible depression of the shoulder, the first rib acting as a fulcrum, so that the inner portion of the clavicle is elevated. The violence continuing forces the head inward and upward behind the sternal portion of the sternomastoid. The lack of adaptability of the joint surfaces serves to explain the *ease of reduction* and the *difficulty of retention* in most cases of luxation in this joint. The recumbent position and various forms of dressing which act on the clavicle directly

or through the shoulder, as in fracture of the clavicle, have been employed. In connection with these the injection of 50 per cent. alcohol, or a similar fluid, with the object of producing a mass of connective tissue around the joint as a sort of new capsule, has been found useful.

The *sternoclavicular joint* is *not particularly liable* to the ordinary *diseases of joints,* in spite of its exposed position and constant motion, for it is well protected by its strong ligaments and interarticular cartilage from strain and injury. As the synovial sac is divided into two by the interarticular cartilage, disease may commence in and be limited to one sac, but, as a rule, the entire joint (both sacs) becomes involved. Owing to the fact that the *anterior sternoclavicular ligament* is the *thinnest and weakest part* of the capsule *swelling* is first evident in front, as a rule, and, when *spontaneous perforation* occurs, the pus usually escapes anteriorly. If, as may happen, it escapes through the posterior ligament it may readily reach the mediastinum. The notable fact that the disease of this joint never results in ankylosis is due chiefly to the entire lack of adaptation of the two bony surfaces and, to a less extent, to the constant slight movement here and the occasional persistence of the interarticular cartilage, after arthritis. The *importance* of bearing in mind *the relations* of this joint to the great vessels behind it is illustrated by a case reported by Mr. Hilton in which a large abscess in the joint received pulsation from the subjacent subclavian or innominate artery and was first thought to be an aneurysm.

The Acromioclavicular Joint.—The acromioclavicular joint depends for its *strength* upon its *ligaments,* for its shallow flat *joint surfaces* are bevelled from above downward and inward and offer *no obstacle to the upward dislocation* of the outer end of the clavicle. This fact explains why this is the common form of dislocation in this joint. The capsule and ligaments of the joint proper are lax and weak, so that effusion into the joint is soon visible. It is the *strong coracoclavicular ligament* (conoid and trapezoid divisions) upon which the strength of the connection between clavicle and scapula depends.

The **upward dislocation** of the outer end of the clavicle may be complete or partial, and in the former case the coracoclavicular as well as the acromioclavicular ligaments are torn, in the latter case the former may be partly torn or merely stretched. In complete dislocation the outer end of the clavicle rides up above the acromion and may be *displaced* outward over the latter. The *cause* is usually a blow upon the point of the shoulder, probably associated with a vigorous contraction of the trapezius, whereby the clavicle is prevented from becoming depressed with the acromion. The rarity of **downward or subacromial dislocation** of the outer end of the clavicle is explained by the oblique direction of the joint surfaces. The cause in most cases was direct violence applied to the outer end of the clavicle.

Whereas *reduction* is commonly easy in both forms, *retention* is difficult, as there is nothing in the shape of the bones to hold them together and the ligaments are torn. In the common upward form upward pressure of the shoulder through the arm and downward pressure on the

outer end of the clavicle are accomplished by various retentive dressings, but the necessary continuous retention is very difficult. As in dislocation of the sternoclavicular joint the injection of irritants, like 50 per cent. alcohol, to stimulate peri-articular connective-tissue formation, which afterward contracts and helps to hold the bones together, I have found useful, especially in the incomplete forms. Some patients are seriously *disabled* by this accident, others but little.

In this connection it may be noticed that the **movements** of this joint allow the glenoid cavity to *maintain or alter* its *relative position* in the movements of the shoulder around the sternoclavicular joint as a centre. Thus in raising the arm the extent of this movement is much increased by the elevation of the glenoid cavity, so as to look upward, the scapula moving on an anteroposterior axis through this joint. Again, as the shoulder moves forward for a blow or shove or in a fall upon the hand, the glenoid cavity is turned forward, so that it may be as nearly as possible at right angles to the long axis of the humerus which, it it can thus best support. In this way a strong forward "blow from the shoulder" is possible. Otherwise the strain comes upon the capsule of the joint and tends to dislocate the shoulder. This forward position of the glenoid cavity is due to a movement of the scapula on a vertical axis passing through this joint. Impairment of this joint by accident or disease may, therefore, cause a limitation in certain movements of the upper limb or an insecurity of the shoulder joint.

Subclavicular Soft Parts.—The *interspace* between the *sternal and clavicular portions* of the *pectoralis major* can often be distinguished on the surface just below the clavicle. The sternal portion is often removed in the operation for carcinoma of the breast. The clavicular portion is the more superficial of the two. The *pectoral fascia* is firmly connected with the pectoralis major. We may usually be sure that we have divided the pectoralis major when we reach a cellular layer, though Heath describes a cellular interval which sometimes lies between two planes of its muscle fibers and may be mistaken for the space beneath it. On removal of the pectoralis major we expose the *pectoralis minor*, from whose upper border, as far as the coracoid process, a strong fascia, the **clavipectoral fascia,** extends up to and is continuous with the sheath of the subclavius muscle, and thence is connected with the clavicle. It is continuous above with the sheath of the axillary vein and the deep cervical fascia. Mesially it is continuous with the deep fascia covering the first two intercostal spaces. The upper part of this fascia, between the coracoid process and the first rib, is particularly firm, and is named the *costocoracoid membrane.* This *fascia* is *pierced by* the cephalic vein, the acromiothoracic artery, and the anterior thoracic nerve, and *covers* the first portion of the axillary vessels and the brachial plexus. The clavipectoral fascia *splits to ensheath the pectoralis minor* and unites below it into a single triangular sheet which extends laterally to the sheath of the coracobrachialis and inferiorly to the axillary fascia in the floor of the axilla, the hollow of which it serves to preserve, hence the name "*suspensory ligament of the axilla.*"

The axillary vein lies below and internal to the artery, which it overlaps, owing to its greater size. Hence when the **axillary artery** is *tied* in its first portion the *aneurysm needle* is passed from below, to avoid injury to the vein. The axillary artery is *crossed in front by the cephalic vein* in its passage to reach the axillary vein. A part of or the entire cephalic vein occasionally crosses in front of the clavicle to join the external jugular vein. One of the cords of the *brachial plexus* lies in contact with and on the same plane as the artery and may be and has been mistaken for it in ligation of the artery. These main vessels and nerves are surrounded by more or less *areolar and fatty tissue* containing *lymphatic vessels* and the subclavicular group of *nodes,* which may be involved secondarily to those of the axilla, with which they are continuous. Their efferent vessels form the subclavian trunk and in addition communicate with the supraclavicular group of the deep cervical nodes above. Along this areolar tissue deep infection and abscess may extend from the neck to the axilla, and vice versa.

The Posterior or Scapular Region.

The skin covering this region is firm, and there is but little *subcutaneous tissue.* The thick **deep fascia,** by its attachment to bone around the origin of the supra- and infraspinatus and the teres minor muscles which it covers, encloses them in an *osseo-aponeurotic compartment,* open only toward the insertion of the muscles on the great tuberosity of the humerus. Hence in case of abscess under this fascia or ecchymosis from fracture of the scapula the pus or blood cannot readily reach the surface, but follows the muscle sheaths to the humeral head and appears from beneath the deltoid. The *firmness* of this fascia is such that it is difficult to decide whether dense tumors growing from it are connected with the fascia or the bone. The **scapula** is *held in place* by the coraco- and acromioclavicular ligaments and by the serratus magnus, rhomboids, trapezius, and levator scapulæ muscles. The so-called "*winged scapula,*" or luxation of the scapula, in which the lower part of or the entire vertebral border projects backward from the chest wall, is due to *paralysis* of the lower part or the whole of the *serratus magnus muscle,* which is supplied by the long thoracic nerve. In ankylosis of the shoulder joint the mobility of the scapula diminishes the functional disability.

Fracture *of the body of the scapula* is comparatively *rare,* owing to the mobility of the bone, the adaptation of its shape to the curve of the thorax it covers, its thick muscular covering, the elasticity of the ribs beneath, and the soft muscular pad of the subscapularis and serratus magnus between it and the chest wall. In case of fracture the *fragments* are *splinted* by the muscles attached on both sides of it, which prevent much displacement. The *acromion* is *more exposed to injury* and fracture than other parts of the bone. Some consider many cases of supposed fracture of the acromion as examples of *epiphyseal separation* from the spine, which may occur before the twentieth year, when the epiphyseal union ossifies. But clinically most cases are found to be nearer the end of the

acromion, *i. e.*, just in front of the acromioclavicular joint. The dense fibrous tissue, which covers this process and is derived from the two muscles attached to it (deltoid and trapezius), and its thick periosteum help to explain why much *displacement* is *uncommon* and why many fractures are subperiosteal and crepitus is wanting. When the fracture is in front of the acromioclavicular joint the deltoid may pull the fragment slightly downward, causing a little flattening of the tip of the shoulder, but there can be no displacement of the scapula and arm. When the fracture is behind the joint the scapula may still be connected by the coracoclavicular ligaments to the clavicle, and there can be but little if any displacement of the arm. Bony union is said to be the exception. It should be remembered that in some cases the union of the acromion and spine does not ossify, so that the presence of motion and fibrous union between these two parts does not necessarily imply fracture or an epiphyseal separation.

Fracture of the coracoid process may occasionally occur as a result of violence or muscular action. Usually it is only one of several fractures resulting from severe violence. In some cases the *line of fracture*, being near the base of the process in the line of the epiphyseal cartilage, which ossifies during the fifteenth year, has suggested that the case was one of epiphyseal separation. Although three powerful muscles are attached to the coracoid process, *displacement* is *usually slight*, owing to the attachment of the coracoclavicular ligaments, which are seldom torn.

The **rare fracture** of the **surgical neck of the scapula** involves the separation of the coracoid process and the glenoid fossa, together with the triceps attachment, from the rest of the bone. The arm is *displaced* downward, as in a subglenoid dislocation, if the coracoclavicular, coracoacromial, and spinoglenoid ligaments are torn, but these ligaments are usually untorn and limit the displacement. It is easily distinguished from dislocation of the humerus by crepitus, the ease of reduction, the equal ease of recurrence of the displacement, and by the accompanying displacement of the coracoid process.

Tumors of various kinds, especially osteoma, enchondroma, and sarcoma, grow from the scapula and require partial or complete excision. In **partial excision** those parts which are of special importance for the function of the arm—*i. e.*, the glenoid fossa, coracoid and acromion processes, should be preserved if possible. The **entire bone** is **removed** with or without the arm in sarcoma. In malignant tumors of the upper end of the humerus and some sarcomata of the axilla the upper extremity, scapula, and outer two-thirds of the clavicle are removed (**interscapulothoracic amputation** of the arm), after first ligating the subclavian artery. The latter renders the operation bloodless except for the posterior scapular artery along the vertebral border and the suprascapular artery in the supra- and infraspinous fossæ, these arteries being branches of the first portion of the subclavian. In **complete excision** of the scapula (without ligature of the subclavian) the *subscapular artery*, which runs along near the lower border of the subscapularis muscle and gives off the large dorsalis scapulæ branch crossing the axillary border onto the infra-

spinous fossa, must also be taken into account. This branch of the axillary artery *anastomoses with* the posterior scapular and suprascapular branches of the subclavian, and is an *important factor* in the *collateral circulation* after ligature of the third portion of the subclavian or the first portion of the axillary artery. The *anastomoses on the acromion* between the suprascapular branch of the subclavian and the acromiothoracic and circumflex branches of the axillary assist in this collateral circulation. For *resection* of the scapula a horizontal *incision* along the spine and a vertical one along the vertebral border (Ollier's) are very serviceable.

The **suprascapular nerve** is a branch of the fifth cervical and receives a branch from the third and fourth cervical nerves, from which is derived the *phrenic nerve.* The latter also communicates with the *nerve to the subclavius* and with the supra-acromial nerve, and these connections explain the *reflex relations* between the diaphragm or liver and the shoulder, *i. e.,* hiccough from inflammation of the shoulder and pain in the right shoulder and shoulder-tip pain in perihepatitis, gall-bladder lesions, etc.

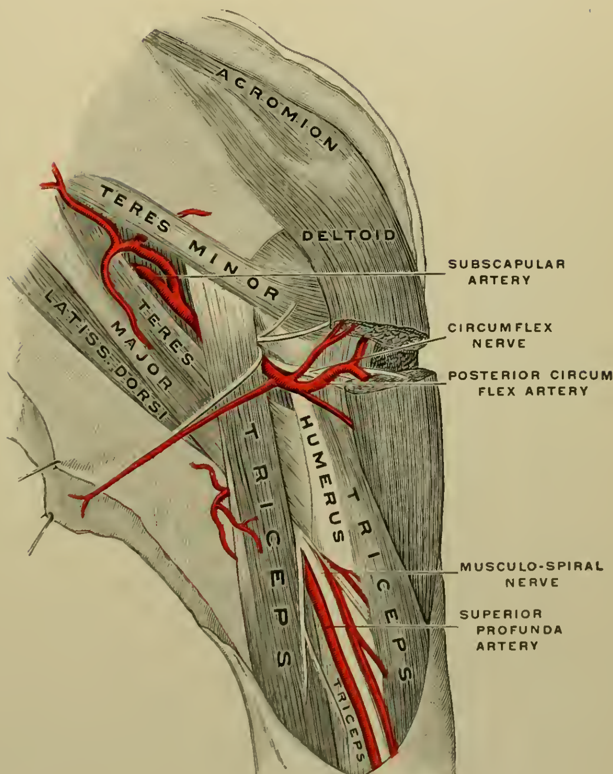
The External or Deltoid Region.

This is equal in extent to that of the **deltoid muscle,** which *covers* the upper end of the humerus and the muscles inserted into it, the shoulder joint, the coracoid process and its muscles, and the coraco-acromial ligament. The *subcutaneous fatty layer* over the deltoid is often well-developed, and is a favorite situation for *lipoma.* The *deep fascia* ensheaths the deltoid and is closely bound to it. In subglenoid or subcoracoid *dislocation* of the shoulder the head of the humerus no longer bolsters out the *deltoid,* so that the latter is *flattened* and hangs straight down from the acromion process, which is thereby rendered more prominent and angular. Moreover, the attachments of the deltoid being more widely separated than normal, the muscle is *put on the stretch,* which still further flattens the region and causes a fold at the insertion of the muscle. To *relax the deltoid* the dislocated arm is usually held in the abducted position. If this position is exaggerated, so that the deltoid is very lax, the fingers may be thrust beneath the acromion into the gap left by the dislocated head of the humerus, and in thin subjects the glenoid cavity may even be felt.

The *deltoid region* may be *flattened* and a depression be felt beneath the acromion in certain cases where the head sinks away from its socket, owing to *paralysis and atrophy of the muscle,* which is *supplied by* the **circumflex nerve** (Fig. 61). This nerve *winds around* the *surgical neck* of the humerus a little above the posterior circumflex artery, which is 5 cm. (2 in.) below the acromion. The nerve may be *torn, bruised, or stretched* in dislocations of the shoulder, in violent attempts at their reduction, in fractures of the surgical neck of the humerus, in some birth palsies, and it may very rarely be bruised in contusion of the shoulder. As it also *supplies the shoulder joint* an inflammation of the latter extending along the nerve may cause a neuritis and lead to paralysis of the muscle (Erb). This nerve also gives off a *cutaneous branch* which,

PLATE XII

FIG. 61



Posterior Region of the Shoulder. Right side. (Joessel.)

winding around the posterior border of the muscle, *supplies the skin* over its *lower third* (and below it). Thus, according to Anger, we may test the sensibility of this cutaneous branch after dislocations of the shoulder, and thereon base our prognosis as to the future condition of the muscle, for it is not infrequently paralyzed temporarily or permanently.

The deltoid is *not the only abductor* of the arm, being assisted by the supraspinatus, and in initiating this movement the latter is probably the most active; but in paralysis of the deltoid the power of abduction is usually slight. In *excision* of the shoulder joint the nearer the *incision* is made to the *anterior border* of the deltoid the less of the muscle will be paralyzed by cutting its nerve supply and the smaller will be the branches of the posterior circumflex artery to be divided.

Beneath the deltoid, in the layer of loose connective tissue which facilitates the movements of the underlying head of the humerus, is the *subdeltoid or subacromial bursa,* which still further facilitates these movements. As its name implies, this bursa also extends beneath the acromion process and the coraco-acromial ligament, and this portion is sometimes partly separated from the subdeltoid portion by a constriction. *Beneath the bursa* are the great tuberosity of the humerus and the supraspinatus tendon, but there is *no communication with the joint* except when the supraspinatus tendon is ruptured in dislocation. This bursa may *hold* about an ounce when distended with fluid, as it sometimes is, causing an undue *prominence* of the deltoid. In case of *abscess* of this bursa the pus may reach the surface at either edge of the muscle, usually the anterior edge, rarely through it. From the point of view of *operative incision* the shoulder *joint* is *only covered* by the skin, the deltoid, and the capsule.

The Shoulder Joint.—The shoulder joint is one that relies for its *strength* largely upon the *surrounding muscles,* a variety of joint most *liable to dislocation.* The laxity of the capsule (especially its inferior part) and the fact that the articular surfaces are held together by muscular action aided by *atmospheric pressure* is shown by the admission of air into the joint, dissected free of its muscular covering. Thereupon the head of the humerus falls away from the glenoid cavity by a considerable interval. The same occurs in cases of old standing paralysis of the deltoid. The acromion and coracoid processes, and the coraco-acromial ligament connecting them, form an *arch above the joint,* protecting it but separated from it by the interposed tendon of the supraspinatus and the capsule.

The **muscles strengthening the capsule** are the subscapularis in front, the supraspinatus above, and the infraspinatus and teres minor behind. The tendons of these muscles are *blended with the capsule* in their passage to the small and great tuberosities of the humeral head. They are continuous with one another and are assisted in supporting the joint by the long head of the triceps below and the long head of the *biceps* above. The latter tendon in its passage through the bicipital groove, which is converted into a canal by the transverse ligament, is accompanied by a *tubular prolongation* of the *synovial membrane* forming a kind of vaginal sheath for it. There is another constant *gap in the capsule* by which the synovial sac communicates with the *subscapular bursa,* a large pouch

between the upper part of the subscapularis and the root of the coracoid process, together with the adjoining part of the neck of the scapula. The crescentic gap leading from the joint into this bursa lies just in front of the upper end of the inner or anterior margin of the glenoid cavity, between the superior and middle glenohumeral bands. A *bursa* beneath the infraspinatus rarely communicates with the joint. The *capsule is unprotected* antero-inferiorly between the subscapularis and the long head of the triceps, where the head can be felt by the hand in the axilla. The *axillary vessels* and *nerves* (Figs. 64, 68) lie to the inner side of the joint, separated from it by the subscapularis tendon.

In *joint disease* with effusion the shoulder appears full and rounded by reason of the distended capsule, which may cause a separation of the two bones of more than 12 mm. ($\frac{1}{2}$ in.) (Braune). In artificial *distention* the arm becomes slightly *extended* and *rotated inward*, a position commonly found in joint disease and perhaps due partly to the rigid contraction of the muscles, of which the latissimus dorsi may have a slight advantage and be responsible for the extension and inward rotation. Special prominences occur in the bicipital and subscapular diverticula. Thus a *swelling* often appears at an early stage *in the groove* between the deltoid and great pectoral muscles. This swelling is sometimes bilobed on account of the unyielding biceps tendon. *Fluctuation* can best be *felt* through the axilla, at the uncovered part of the capsule below the subscapularis. If suppuration occurs the *pus usually escapes* through one of the diverticula, most often the one around the biceps tendon. In the latter case it may extend some distance along and beyond the bicipital groove. If it escapes through the subscapular bursa it is apt to spread between the muscle and the scapula and point at the lower and dorsal part of the axilla. Although the shoulder joint is liable to all forms of *joint disease*, the latter are not particularly common here. This fact is partly due to its ample covering of soft parts, the mobility of the shoulder girdle (diminishing strains), the weight of the upper extremity resisting the pressure between the joint surfaces and the laxity of the capsule and its synovial lining lessening the tendency to joint tension from effusion. As the result of disease the various forms of *ankylosis* occasionally occur, and in such cases Tillaux has suggested division of the clavicle and the formation of a false joint to afford more free movement.

The *long tendon of the biceps* strengthens the upper part of the joint, keeps the humerus against the glenoid cavity, and prevents it from being pulled down when the arm is abducted. It also prevents the deltoid from pressing the head of the bone too strongly against the acromion. It is rarely ruptured and seldom displaced from its groove unless one of the tuberosities is torn away, as occasionally occurs in dislocation of the shoulder. The *inner margin* of the *glenoid cavity* is the stronger and more prominent, especially below, a fact which indicates an attempt to fortify a weak part of the joint where the head most often leaves the socket in dislocation.

When the arm hangs at the side the entire head may be to the outer side of the coracoid process in this position, but the shape of this process

PLATE XIII

FIG. 62

Right Shoulder Joint. Anteroposterior. Arm rotated outward. Male, aged thirty-three years.

1. Upper border of scapula.
2. Attachment of spine of scapula.
3. Spine of scapula.
4. Acromion.
5. Coracoid process.
6. Glenoid cavity.
7. Second rib.
8. Fifth rib.

varies and often overlies the inner part of the head. Especially when the point of the shoulder droops, the tip of the coracoid is often in contact with the lesser tuberosity and a bursa (subcoracoid) intervenes between them (Goldthwaite). With the arm hanging at the side the glenoid cavity looks outward and forward, nearly midway between the sagittal and frontal planes of the body, and at least two-thirds of the head of the humerus are not in contact with it. The glenoid fossa is less than half as large as the articular portion of the head of the humerus on horizontal section, and about two-thirds as large on vertical section. Thus a considerable portion of the head of the humerus is always out of the socket and in contact with the capsule, and in abduction of the arm to 90 degrees the head of the bone presses against and puts on the stretch the lower unprotected part of the capsule, between the subscapularis and triceps tendons. It is in this position, with or without outward rotation, that dislocation of the shoulder is most likely to occur.

In *abduction* of the arm to a right angle the great tuberosity abuts against the upper edge of the glenoid cavity and the upper end of the outer aspect of the humerus against the coraco-acromial arch. This is true whether the arm is abducted laterally or in the forward position, as in falls on the hand. *Further abduction* is *due to* the rotation of the scapula, but if the latter is kept from rotating by being held mechanically or by a muscular spasm (serratus magnus), and if the motion of abduction is continued, a *new centre of motion* is formed at the point of contact of the humerus with the coraco-acromial arch, and the prominence of the head is forced down against the lower and inner tense part of the capsule, rupturing it at its thinnest and weakest part. Such is the common **mechanism of dislocation** in cases due to indirect or to muscular violence. Rarely the head may leave the socket more anteriorly, or very rarely posteriorly.

The *infrequency* of the injury in the *first two decades* of life is interesting in connection with Krönlein's theory that in this period fracture of the clavicle is the equivalent of dislocation of the shoulder by direct violence, and dislocation of the elbow the equivalent of dislocation of the shoulder by indirect violence.

Dislocations of the shoulder are as *numerous* as all other dislocations combined, perhaps more so. This *frequency* is fully *explained* by (1) the structure of the joint (the shallowness of the glenoid fossa, the large size of the humeral head, the freedom of motion, the long leverage of the arm, the thinness and laxity of the capsule and its dependence upon the muscles for its strength); and (2) the exposure of the shoulder to indirect and direct violence. Dislocations of the shoulder are *classified, according to the displacement* of the humeral head, into (1) anterior or subcoracoid, the common form; (2) downward or subglenoid, not common; (3) backward or subspinous, rare; and (4) upward or supraglenoid, very rare. Only the first two forms demand our consideration.

In subcoracoid dislocations the *head* of the humerus *escaping* through the rent in the antero-inferior part of the capsule is **displaced primarily** downward and somewhat forward. Indeed, some downward displace-

ment is necessary to allow the head to get beneath the coracoid. But the further downward displacement is resisted by the untorn part of the capsule (posterior and superior parts), whose attachment to the anatomical neck serves as a *new centre of motion*, so that when the elbow is lowered after abduction has ceased, the head, the short arm of the lever, rises along the inner side of the glenoid cavity. This **secondary displacement** to a final position, approximately beneath the coracoid (subcoracoid), is also *partly effected by* the contraction of such *muscles* as the pectoralis major, latissimus dorsi, and deltoid. The *extent of* this secondary inward *displacement is determined* largely by the resistance of the untorn portion of the capsule, the continuance of the dislocating violence, and the degree of contraction of the adductor muscles. Thus the head may rarely be displaced internal to the coracoid process, giving rise to the subvariety "**intracoracoid**" (Fig. 63).

Fig. 63

Intracoracoid dislocation.

In the **subcoracoid form** the *head* of the bone *lies* behind the coraco-brachialis and the short head of the biceps and against the edge of the glenoid fossa, or the side of the neck of the scapula just internal to it. The posterior part of the anatomical neck may rest on the anterior lip of the glenoid cavity. In the **intracoracoidal** or **subclavicular** variety *it lies* farther backward and inward on the neck of the scapula and against the chest wall on the serratus magnus, having passed behind the muscles arising from the coracoid process. The head is thus internal, anterior, and a little inferior to its normal position.

The **subscapularis muscle** is sometimes pressed inward and separated from the scapula by the interposed humeral head, but in many cases it is torn from its lower border upward to a greater or less extent. Thus the subscapularis may intervene in whole or in part between the coracoid process and the head, or the latter, escaping in front of the muscle, may lie close against the beak of the coracoid, behind the coracobrachialis and short head of the biceps. The *attachment* to the humerus *of the supraspinatus* is probably often torn, that of the infraspinatus less often, or, in place of this rupture of the tendons, one or more facets of the **great tuberosity** may be *torn off*. This latter accident is of importance because

it *opens the way for the long biceps tendon* to escape from its groove, slip over the head, and become engaged between the head and the glenoid cavity, where it may offer a serious obstacle to reduction. The *rupture* or avulsion of the *supra-* and *infraspinatus tendons,* and their consequent retraction under the acromion, may impair the subsequent motion of the joint by their loss of control over the humerus. They may also become interposed between the head and its socket, so as to oppose complete reduction, or they may open up the subacromial bursa and favor the recurrence of dislocation by lengthening and weakening the capsule. When the coracoid process rests against the lesser tuberosity, in drooping of the shoulder (p. 177), this tuberosity forms a new centre of motion, and the biceps tendon then tends to draw the head downward and inward and thus becomes a cause of recurrent dislocation (Goldthwaite). The *axillary vessels and nerves* are pressed inward and sometimes ruptured, contused, or compressed, causing pain, edema, etc.

In the subglenoid variety the *head* usually *rests* against the flattened upper end of the axillary border of the scapula on the inner side of the triceps tendon, the latter preventing its displacement directly downward. It thus *lies* below and a little internal and anterior to its normal position. It also lies beneath the subscapularis tendon, which is much stretched or torn. The *rent in the capsule* differs from that in the subcoracoid form in not extending so far upward along the anterior edge of the glenoid cavity. The resistance of this untorn anterior part of the capsule seems to be what prevents the head from reaching the subcoracoid position, although in some cases this dislocation may be transformed into a subcoracoid by movements of the arm or even by muscular action. The *supraspinatus* and often the *infraspinatus* are *torn* from their attachments, or the *tuberosity is avulsed* from the humerus. The *cause* of the subglenoid form has almost always been a forcible elevation of the arm.

The **symptoms** in both forms are mainly *due* to the absence of the head from its normal position, the presence of the head in an abnormal position, and the consequent altered position or action of the muscles. The *absence of the head* from its socket accounts largely for the flattening of the deltoid region, and, in the subcoracoid form, the *empty glenoid socket* can be *felt* through the axilla. In the subglenoid form we can *feel the head* through the axilla, lying below the glenoid fossa, 12 to 25 mm. ($\frac{1}{2}$ to 1 in.) below the coracoid process, while in the subcoracoid form it forms a hard prominence of the anterior axillary wall, just below the coracoid process, and causes a fulness of the outer part of the infraclavicular fossa. The *axis of the arm* prolonged upward passes below or internal to the glenoid cavity. The *deltoid is stretched* by the increased separation of its attachments, and this not only increases the *flattening* of the deltoid region and the angular prominence of the acromion, but causes the arm to be *abducted,* which is more marked in the subglenoid variety, as in this form the deltoid is more stretched. Below the prominent edge of the acromion we can feel a depression instead of the natural resistance of the tuberosities.

As the head is displaced somewhat downward in both forms, *measure-*

ment from the angle of the acromion to the external condyle of the humerus should show *lengthening* as compared with the opposite limb. But owing to the relative position of these two points of measurement, in a plane external to that of the glenoid cavity, abduction causes a measured shortening in the normal arm and still more so in the dislocated arm, when the head is displaced more or less inward. Hence the measured *lengthening will depend on the degree of abduction,* and may be altogether wanting or replaced by shortening, though seldom so in the subglenoid form, in spite of the greater abduction, on account of the greater lengthening in this form. The vertical dimension of the axilla is increased because the axillary folds, formed by the pectoralis major and latissimus dorsi, are displaced downward with the humerus, to which they are attached. The elbow is flexed by reason of the tension of the biceps. The elbow cannot be made to touch the thorax, for, on account of the rotundity of the thorax, both ends of the straight humerus cannot touch it at the same time, and in a dislocation of the shoulder the head of the bone is practically in contact with the thorax. The *diagnosis* between subcoracoid and subglenoid dislocations can usually be readily made from the differences noted in the symptoms given above.

Reduction.—The *obstacles* to this may be the tension of the untorn portion of the capsule, opposing the movement of the head toward the socket, the approximation of the sides of the rent in the capsule, the interposition of portions of the capsule or of the biceps tendon, the contraction and rigidity of the muscles, the edge of the glenoid cavity, and, rarely, the interposition of the subscapularis tendon.

The **most frequent obstacles** are the opposition of the untorn anterior part of the capsule and the contraction of the muscles, and these, as well as most other obstacles, may be *avoided by abduction and outward rotation* of the arm. *Traction* in this position, with or without *direct pressure* on the head toward the glenoid cavity, is successful in the great majority of cases. Inward rotation may increase the success of this method. Success in methods employing traction, in fact, in all methods, is also largely dependent upon the efficient *fixation of the scapula* by the surgeon, his assistant, bandages, or apparatus. Stimson[1] has successfully employed a modification of this method by exerting continued traction by a weight on the abducted arm, the latter passing through a hole in a canvas cot. The continued traction of the weight tiring out the muscular contraction, reduction occurs painlessly and spontaneously within six minutes. Similarly the weight of the body may be used to produce the traction, by the assistant raising up the abducted arm of the patient, who lies on the floor. *Traction upward,* though formerly employed, is *objectionable* on account of the risk of increasing the laceration of the capsule and of injuring the axillary vessels by stretching them around the head of the humerus. Although this method is theoretically suggested by the position of the head in the subglenoid variety, yet, on account of the risks mentioned, trial should first be made of direct reposition by pressure on the

[1] Fractures and Dislocations, fourth ed., p. 564.

head, or this combined with traction and rotation in the abducted position.

In the methods of **reduction by manipulation,** *rotation inward* has long been employed to turn the head of the bone into the socket opposite to which it had been brought by traction. Inward rotation constitutes the *last step* in the pure manipulative method now most in use, that of Kocher. This is especially applicable in the subcoracoid form. In **Kocher's method** the flexed elbow is pressed against the side (*adduction*) and the arm *rotated outward* until the forearm points directly outward; the arm, rotated outward, is then *carried forward* (upward) and *slightly inward,* and *rotated inward,* carrying the hand over to the opposite shoulder. Reduction occurs in the final rotation inward or in the movement forward and inward. Of course, flexion of the elbow, in this and other methods of reduction, relaxes the biceps and provides a lever for the rotation and other movements in the manipulation. Farabeuf thus explains the *mechanism of the manipulation.* The untorn *posterior portion of the capsule* is the efficient agent. This is tightened by the adduction, so as to prevent the posterior surface of the humerus from moving inward or forward when the arm is rotated outward. Hence the attachment of this part of the capsule serves as a fixed point about which the head starts to roll or wind outward, in outward rotation, toward the outer aspect of the socket. This movement also relaxes the tendons of the scapular muscles and removes them from the fossa. In the forward movement, with slight adduction, the head, forming the short arm of the lever and turning upon the same fixed point, is thrown backward and farther outward toward a point opposite the socket, but separated from it by the capsule, so that the final inward rotation, unwinding the capsule, leaves the head in place. In the forward movement the upper portion of the capsule, the deltoid, and the coracobrachialis are relaxed, and in the inward rotation the subscapularis is also relaxed. This method is also applicable to old cases, but there is some danger of fracture of the humerus in the outward rotation. Anesthesia, of course, most effectively relaxes the muscles, but is not often necessary except in cases of long standing.

Associated Injuries and Complications.—Associated injuries and complications of dislocation of the shoulder, in addition to those mentioned, may occur either *at the time of dislocation or during reduction,* and it is often difficult to say at which time a given complication has occurred. **Fracture of the anatomical or surgical neck** is rare, and is indicated by the failure of the head, which is out of the socket, to share the movements of the arm. The dislocated and fractured fragment may sometimes be reduced by direct pressure in the abducted position. Failing in this, the following plans were formerly tried: (1) consolidation of the fracture and then reduction; (2) prevention of union and the formation of a false joint; (3) excision. Open incision is preferable, and McBurney has demonstrated the usefulness, in accomplishing reduction, of a stout bent hook introduced into a hole drilled in the upper fragment in such cases, especially in fractures of the surgical neck. Fracture of the neighboring processes or of the shaft have also been observed.

Injury to the nerves, except of a slight and transitory nature, are *not common*; they occur most often during reduction and in the subglenoid variety in which the nerves are tightly stretched around the head. The *circumflex nerve* (see also p. 174) suffers most often, and has been entirely or partly ruptured, stretched, or compressed. The main nerve trunks have also been compressed or stretched.

Serious injury to the **bloodvessels** is *not common*, and it is often doubtful whether the injury occurred during the dislocation or its reduction. The *axillary vein* alone has been ruptured in four cases, the vein and artery in three, but in the majority the *axillary artery or one of its branches* has been the vessel injured.[1] In some of the latter there was complete or partial rupture of all of the coats of the artery, while in others the coats were so injured that rupture or the formation of an *aneurysm* followed later. The rupture is usually *high up*, where the head pressed inward upon the vessel, and in some cases it appeared to be due to the tearing off of a branch, the subscapular or circumflex, which run almost directly outward, where they are fixed to the tissues among which they branch. Again, the branches just named have also been torn across at or near their origin, in which case the radial pulse would persist. In *old dislocations* the vessels, especially the outermost one, the artery, becoming adherent to the bone or embedded in scar tissue, are *more likely to be ruptured in reduction*, for their elasticity is diminished and the strain comes on a shorter segment of the vessel, *i. e.*, the segment above the adhesion to the bone. If the artery is atheromatous the danger is still greater.

Fracture of the Anatomical Neck.—Fracture of the anatomical neck without an additional line of fracture through the tuberosities is a *rare* and obscure form of injury, and occurs most often in connection with dislocation of the shoulder. The shortness and slight degree of constriction of the neck account for the rare occurrence of this fracture. When the line of fracture passes through the tuberosities the outer part of it is extracapsular, for the outer part of the capsule is attached exactly to the anatomical neck, while internally it is attached some distance below it. From the latter point capsular fibers are reflected upward to the lower margin of the articular head, and these fibers blend with the periosteum and usually, but not always, are in part untorn and connect the head with the shaft in fracture of the anatomical neck. When the head has a slight vascular connection with the rest of the bone, and perhaps when it has none, it does not necessarily necrose, but *repair is possible*, being carried on largely by the lower fragment.

The *symptoms* are *obscure*. *Crepitus* may be absent, owing to impaction or the ease with which the small upper fragment within the socket shares the movement of the lower fragment. The *lower fragment* may be *displaced* upward and backward by the action of the deltoid and other muscles, and in this case there is likely to be slight shortening of the arm.

[1] Stimson, Fractures and Dislocations, fourth ed., p. 453.

Again, the upper end of the lower fragment may be displaced forward and inward by the muscles attached to the bicipital ridges and groove. Up-and-down movements of the lower fragment may be unusually free and accompanied by pain and possibly by crepitus. If impaction of the fragments occurs, as it may readily do, there may be some flattening of the deltoid.

Separation of the Upper Epiphysis.—Separation of the upper epiphysis may take place and has been observed at any time from birth to the age of nineteen, when the upper end usually joins the shaft. The *upper epiphysis comprises* the head and tuberosities, and its *lower border runs* upward and outward along the lower and inner half of the anatomical neck and then transversely under or through the tuberosities to the outer edge, where it lies above part of the insertion of the teres minor. The upper end of the shaft is shaped like a low cone, the height of the cone increasing with age, as does the depth of the corresponding cup in the head. Owing to this shape, the nearly transverse direction of the epiphyseal line, and the width of the humerus at this level complete transverse displacement of the fragments does not often occur, especially as the *periosteum* remains *untorn to some extent*, particularly posteriorly, and where it is torn it is often stripped up from the shaft and torn below the epiphyseal line.

Displacement.—The upper fragment is usually abducted and rotated outward by the muscles attached to the great tuberosity, while the shaft is drawn forward, and usually inward, by the muscles inserted into the bicipital ridges and groove. The anterior edge of the upper end of the shaft forms a distinct forward projection, and can usually be plainly felt 2.5 cm. (1 in.) or more below the acromion. The injury may occasionally cause the *premature ossification* of the conjugal cartilage and the consequent *arrest of growth* of the arm, for the greater part of the growth in length of the humerus takes place at its upper end—four-fifths after the tenth year (Vogt). But arrest of growth has been reported in comparatively few cases. It is much more likely to follow an inflammation of the cartilage (epiphysitis).

The displacement can usually be *reduced* by direct pressure on the projecting fragment combined with traction on the arm, preferably in the completely abducted position, as the upper fragment is already abducted. The forcible raising of the arm beside the head often throws the diaphysis backward into place, as the posterior part of the capsule prevents the epiphysis from moving farther in this direction (Moore). In a few, especially the less recent, cases open incision is required.

Fracture of the Surgical Neck.—The fact that the great majority of fractures of the upper end of the humerus occur between the site of the epiphyseal cartilage and the insertion of the pectoralis and teres major muscles has given the name "surgical neck" to this part of the bone. A fall or blow, or occasionally muscular action, is the *cause*. The upper end is often fixed by the resistance of the capsule, the ligaments, and perhaps the muscles, while the elbow is forced or fixed in a forward or outward position and a blow is received on the outer part of the shoulder

so that a "*cross-strain*" is produced. Fractures of the lower part of the neck are more apt to be oblique.

The **displacement** is commonly as follows: The upper fragment is abducted and rotated outward by the muscles attached to the great tuberosity, while the lower fragment is drawn upward by the deltoid, coracobrachialis, and triceps, unless the fracture is transverse or impacted, and its upper end is drawn inward by the muscles attached to the bicipital groove and ridges and by the continuation of the fracturing force. When so displaced the upper end of the lower fragment may form a projection in the axilla, and the elbow may be so abducted as to alter the axis of the limb. The direction of this axis indicates the position of the upper end of the lower fragment. This displacement is *by no means constant,* and in the majority of cases it is too *slight* to be clinically recognizable, especially through the swollen tissues. In such cases the failure of the tuberosities to share in the rotation imparted to the elbow is an important diagnostic sign. I have had one case where the sharp upper end of the lower fragment perforated and button-holed the deltoid anteriorly, and required an operation to dislodge and replace it.

Traction in the abducted position, aided by pressure on the lower fragment, reduces the displacement. In adopting a *suitable dressing* for these cases the action of the muscles mentioned above as producing the displacement must be opposed, which may be partly effected by using traction by means of weights or the weight of the arm. In some cases the partly abducted position helps to maintain reduction of the displacement.

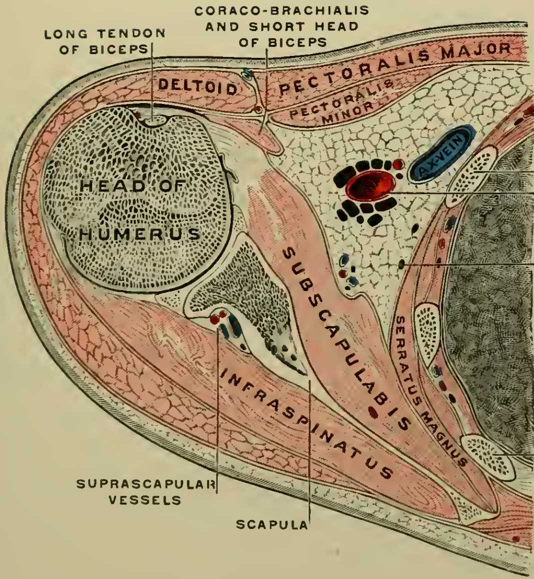
Excision of the Shoulder Joint.—From an operative point of view the shoulder joint is covered only by the skin and the deltoid muscle, and hence is very accessible. It is *most desirable* for the subsequent function of the arm *to preserve the function of the deltoid* by sparing its nerve (the circumflex), which reaches it from behind, hence the *incision* should be *at or near its anterior border.* With this object in view, the *incision* begins at the edge of the clavicle, above the coracoid process, and passes down along or near the anterior margin of the deltoid. The pectoralis major and cephalic vein are retracted internally, the deltoid externally, and if more room is required the latter may be detached for a distance from the clavicle without disturbing its innervation. The acromial branch of the acromiothoracic artery and the coraco-acromial ligament are divided.

The *capsule is opened* along the long biceps tendon, and, rotating the bone first inward and then outward, the great and then the lesser tuberosity is cleared of muscular attachments by vertical incisions close to the bone, the biceps tendon being drawn aside. The head can then be thrust up through the slit in the capsule and the neck cleared and divided.

A continuation of the above incision for excision affords one of the best methods (*racket method*) of **amputation or disarticulation at the shoulder joint,** and it allows an excision to be followed by an amputation if the case demands it. The vertical **incision** is carried down to the level of the axillary fold and then curved outward so as to pass horizontally through the lower part of the deltoid and around the posterior and inner parts of the arm and then turned upward, under the anterior axillary fold, to end

PLATE XIV

FIG. 64

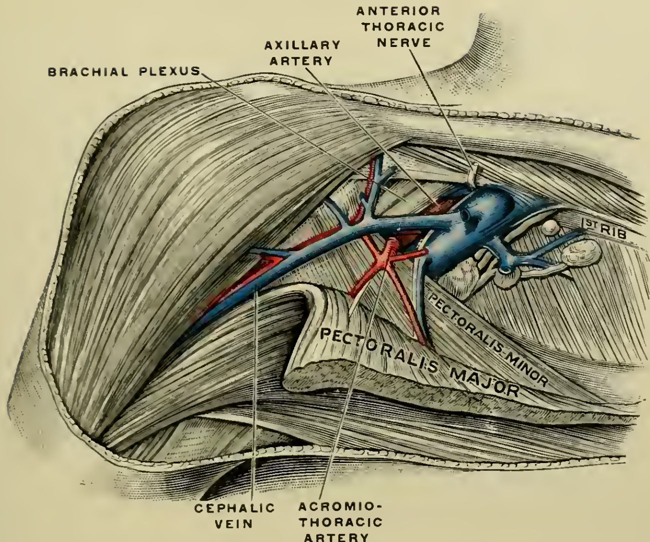


Horizontal Section through the Middle of the Glenoid Cavity. (Testut.)

The arm being adducted, showing the axilla on transverse section. Right side, upper segment of section.

PLATE XV

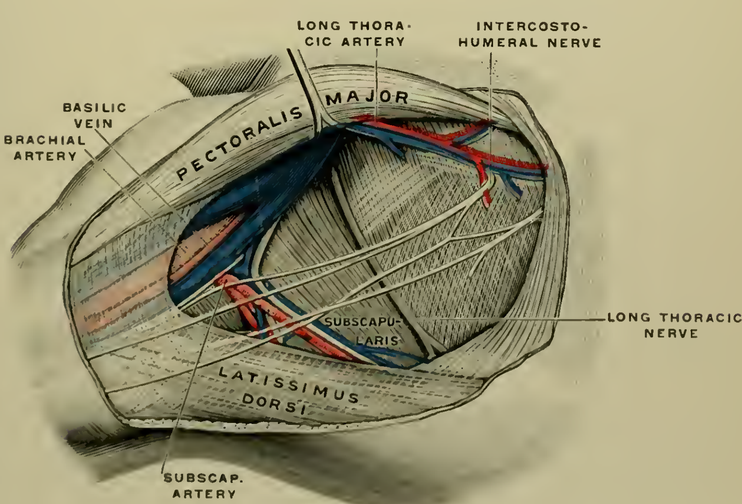
FIG. 65



Infraclavicular Fossa after Removal of the Fasciæ. (Zuckerkandl.)

The pectoralis muscle is separated from the clavicle and turned down.

FIG. 67



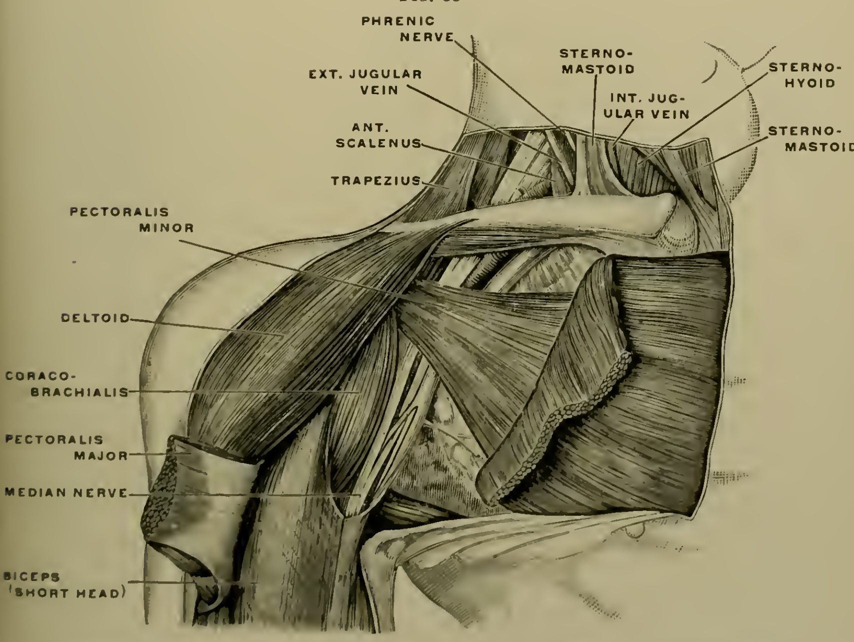
Axilla from Below after Removal of Fasciæ, Connective Tissue, and Lymph Nodes. The pectoralis major is raised up. (Zuckerkandl.)

in the vertical incision. In the vertical incision the cephalic vein and branches of the acromiothoracic artery are ligated. After division of the lower part of the deltoid this muscle, with the trunk of the posterior circumflex artery and the circumflex nerve, can be readily raised from the bone by blunt dissection, exposing the head, around which the capsule is divided. Then the muscular tissues on the inner side, with the vessels and nerves they contain, are divided, after separating them from the bone from above downward to the level of the skin incision. In this step the *main vessels* may be *controlled* by an assistant compressing them in the inner flap between the thumb and fingers of both hands, *or they may be previously ligated* through the skin incision. In freeing the insertions of the teres muscles we must keep close to the bone to avoid the circumflex nerve, which passes back between them to supply the deltoid, the chief muscle of the stump.

The Axilla.

This *pyramidal space* between the chest and the arm may be regarded surgically as a *passageway* between the neck and the upper extremity by which tumors or abscesses may extend from the one to the other region.

Fig. 66



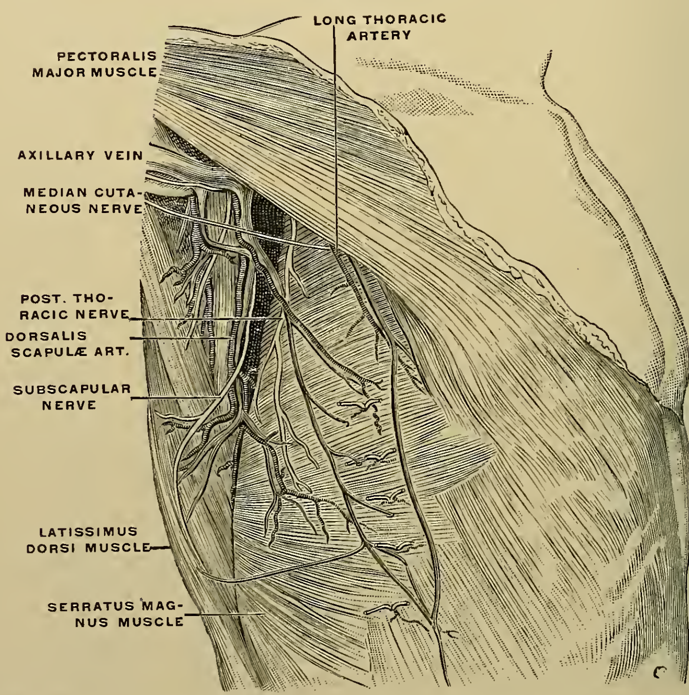
Course of the axillary vessels and nerves and relation to muscles. (After Bardeleben.)

Boundaries (Fig. 64).—**The Anterior Wall** (Figs. 65, 66).—The anterior wall of the axilla is *formed by* the pectoralis major with its sheath, the pectoral fascia, and the pectoralis minor with its sheath, the *clavipectoral*

fascia. From the outer border of the pectoralis minor, where the two layers of its sheath reunite, this clavipectoral fascia extends across in front of the axilla as a triangular sheet to become continuous with the sheath of the coracobrachialis. The lower border or base of this fascia is connected with the axillary fascia and helps to hold up the latter and preserve the hollow of the arm pit.

The Posterior Wall (Figs. 67, 68).—The posterior wall is *formed by* the subscapularis, latissimus dorsi, and teres major muscles, **the inner wall** (Fig. 68) by the upper four ribs and spaces, covered by the serratus magnus muscle. **The outer wall,** so *narrow* as almost to deserve the name angle, is

Fig. 68



Lateral chest wall (internal axillary wall) and posterior axillary wall, with their muscles, vessels, and nerves. (Merkel.)

formed by the humerus covered by the biceps tendons and the coracobrachialis. The **apex** corresponds to the first intercostal space at the commencement of the axillary vessels, and is occupied by these vessels, the lymphatics, and the brachial plexus.

The Base.—The base, represented by the *hollow of the arm pit,* is *formed by* the skin, subcutaneous tissue, and axillary fascia, which extend between the anterior and posterior borders and are continuous with similar structures on the chest wall internally and the arm externally. The **skin** of the base is thin, sensitive, and easily chafed, so that it does not bear the pressure of apparatus well. It is richly provided with hairs, sebaceous and

sweat glands, and these glands or the hair follicles are the starting point of the small *superficial abscesses* often met with here. These may result in secondary glandular abscesses, but they tend to open through the skin, being separated from the axilla by the strong **axillary fascia**. The latter is *continuous with* the pectoral and clavipectoral fascia in front, the fascia of the latissimus dorsi behind, the sheath of the axillary vessels and the deep fascia of the arm externally, and that of the thorax, covering the serratus magnus, internally. It *limits the downward spread* of an axillary abscess or hematoma, as do the other walls of the axilla the extension in their direction. Hence after filling the axilla, and thereby bulging the anterior wall, thrusting back the scapula and obliterating the hollow of the armpit, an *axillary abscess* or hematoma may pass up along the vessels into the supraclavicular fossa and the neck. An *abscess* may occur behind the pectoralis major, between it and the pectoralis minor and clavipectoral fascia. Such an abscess would be separated from the axilla by the strong clavipectoral fascia, and would point along the lower border of the pectoralis major, or possibly in the sulcus between it and the deltoid.

In *opening* an *axillary abscess* the **incision** should be made at the *centre of the base* or floor of the axilla, midway between the anterior and posterior folds, so as *to avoid* the subscapular vessels along the lower border of the subscapularis and the long thoracic along the lower border of the pectoralis minor. It should be *nearer the thoracic or inner wall* than the outer *to avoid* the axillary vessels in the latter situation, but not so near the inner wall or so deeply plunged internally as to wound, as has been done, the long thoracic nerve, which lies on and supplies the serratus magnus. An occasional branch from the axillary or brachial artery crossing beneath the skin of the axilla to the breast, in place of or accessory to the long thoracic, is sometimes found, especially in female subjects, and might be injured in the above incision.

The Contents of the Axilla.—The contents of the axilla *comprise* the axillary vessels and their branches, together with nerves, lymph nodes, and vessels, areolar tissue, and fat. The abundance and looseness of this fatty areolar tissue allow free motion of the arm, but also favor the collection of large quantities of blood or pus.

The Axillary Artery.—The axillary artery keeps to the outer angle or wall of the axilla in all positions of the arm, forming a curve convex outward and upward, when the arm hangs by the side, and a straight line from a little external to the middle of the clavicle to the groove on the inner side of the biceps, when the arm is abducted to 90 degrees and rotated outward.

The Axillary Vein.—The axillary vein *lies* internal to and somewhat below the artery. It *overlaps* the artery, especially during expiration and in its upper and lower parts, being more separated from it in the middle portion, as it takes less of a curve than the artery. When the arm is abducted, as in most operations upon the axilla, the vein is drawn over the artery so as to lie almost entirely in front of it and conceal it. The *outer vena comes* of the brachial artery is often found passing over the

lower part of the axillary artery to join the vein which is formed by the union of the inner vena comes and the basilic vein. This union usually occurs near the lower border of the subscapularis, but sometimes not until just below the clavicle, a condition unfavorable to operations on the artery, as it is crossed by many branches which unite the two veins.

A *muscular slip* from the latissimus dorsi to the pectoralis major may be found crossing the inner aspect of the axillary vessels in the lower part of their course. This may be mistaken for the *coracobrachialis muscle,* which is the *guide to the lower part* of the *axillary artery.* The *latter part* of the artery is superficial and *easily ligated,* remembering that the vein lies to its inner side, separated from it by the internal cutaneous and ulnar nerves, while the musculocutaneous nerve is external and the median nerve in front and externally, its inner root crossing in front of the artery. The *incision* for ligation of the artery is behind the anterior axilla fold in line with that vessel (see above), which lies at the junction of the anterior and middle thirds of the axilla, and is separated from the shoulder joint by the subscapular muscle and its tendon, and from the humerus by the coracobrachialis and the tendons of the biceps.

The **axillary vein** shows the respiratory wave, and its upper part is *held open* by its adhesion to the costocoracoid membrane. Both of these facts increase the liability of the entrance of air in case of its being wounded. The vein is *more often wounded* than the artery, as it is larger, more superficial, and overlies it; but in injuries by traction, as in the reduction of a dislocation, the artery is more often injured than the vein. The relative *frequency* of **aneurysm** of the axillary artery is *attributable to* its nearness to the heart, its abrupt curve, its extensive and frequent movements, and its liability to share in the many lesions of the upper limb. The *axillary nerves* are seldom torn by traction and not often injured by a wound in the axilla, the median being involved most frequently, the musculospiral least frequently, owing to their relative depths.

The Axillary Lymph Nodes.—The axillary lymph nodes are of great *surgical importance,* especially in view of their involvement in septic infection of the upper extremity and in cancerous growths of the breast. They comprise *four or more* fairly distinct *groups:* (1) The *axillary group* (3 to 4) forms a chain along the axillary vein, mostly on its inner aspect, and *receives* the lymphatics of the arm, except those accompanying the cephalic vein; (2) **the pectoral group** (4 to 5), along the course of the long thoracic artery and the outer border of the pectoralis minor, beneath the lower border of the pectoralis major and on the serratus magnus, from the second to the fourth or fifth space, *receives* lymphatics from the mamma, the front and side of the chest, and the abdomen above the umbilicus; (3) the *subscapular group* (6 or more), along the subscapular artery, *receives* lymphatics from the back of the shoulder, thorax, and neck; (4) the *deltopectoral group* (1 to 4), along the cephalic vein just below the clavicle on the costocoracoid membrane, between the deltoid and great pectoral muscles, *receives* lymphatics from the outer part of the arm and the deltoid region; (5) the *subclavicular*

group (6 to 12), beneath and above the pectoralis minor and along the axillary vessels near the apex of the axilla, *receives* the efferents of the other groups either directly or with the intervention of an intermediate group beneath the upper end of the long thoracic vein. Most of their efferents join to form a trunk vessel (subclavian), which passes up over the vein of that name to the terminal lymphatic trunk. One or more efferents usually enter the lower deep cervical nodes (supraclavicular). Of these groups, *the most important* are the first, second, and fifth, and especially the latter two, in connection with cancer of the breast. As they *lie along* the inner or *thoracic wall of the axilla*, it is this wall that should be *palpated* to determine whether there is lymphatic involvement. In persons at all stout it is difficult or impossible to palpate nodes only slightly enlarged. Belonging to the second group are one or two nodes at the level of the third rib which are usually the first to be involved in cancer of the breast.

As a free *communication* exists not only between the nodes of each group, but between the different groups, infection of any one may extend to all the others. Hence in removing the axillary nodes in a case of cancer of the breast we *remove* not the pectoral group only, but *all the groups* and the fatty and areolar tissue which contains lymph vessels. As the axillary nodes communicate with the deep cervical nodes in the supraclavicular fossa, we should examine these in advanced cases to see how far the infection has spread. Some operators regularly remove those in the subclavian triangle in addition to those in the axilla. The axillary nodes are often infected in septic wounds of the areas which their afferents drain, and such infection is the common cause of axillary abscess. They may also be involved in tuberculous and syphilitic enlargement, in lymphosarcoma, and in other conditions accompanied by enlargement of the lymph nodes.

The entire *axilla* up to its apex is *well exposed in Halsted's operation* for carcinoma of the breast, in which the sternal portion of the great pectoral is removed, its clavicular portion incised vertically, and the pectoralis minor divided or removed, thus removing or laying open the anterior axillary wall. The entire cellulo-adipose contents of the axilla, in which the lymph vessels and nodes are embedded, and the veins which they usually accompany are entirely removed in one mass. The dissection is best begun along the axillary vein, which is cleared of its surrounding lymph-bearing tissue after doubly ligating and dividing its many tributaries. The *nodes when diseased* are often *adherent to* the axillary vessels, especially the *vein*, and their pressure on the latter causes the edema of the arm often observed in advanced cases. When necessary to complete a radical operation the vein may be removed with the nodes, and this not only entails no danger to the vitality of the arm but often gives rise to no permanent swelling of the extremity.

Although in inflammatory or other affections of the arm the axillary group of nodes is usually enlarged and painful and often breaks down into an abscess so as to require removal or incision, yet, in several cases of profound sepsis of the arm, ending fatally after a time, I have found no

swelling or tenderness of the nodes in the axilla. But whether this was due to an imperfection of the nodes or to the nature of the infection I am unable to say. At least, having observed a similar condition in the lower extremity in two fatal cases, I consider the prognosis bad when the nodes of the axilla or groin are not enlarged.

THE REGION OF THE ARM OR UPPER ARM.

This *extends* from the lower limit of the "shoulder," the insertion of the pectoralis major internally and the deltoid externally, to the upper limit of the region of the elbow, two or three fingers' breadths above the condyles.

Surface Markings and Landmarks.—Whereas in women, infants, and fat subjects the arm is regularly rounded, in muscular subjects it is flattened on each side and especially prominent in front, owing to the distinctly outlined *biceps muscle.* On either side of the latter is a *groove,* of which the inner is much the more marked and runs from the axilla to the bend of the elbow. It indicates the position of the basilic vein and the *brachial artery,* the course of the latter, in the extended and supinated arm, corresponding to a line drawn along the inner border of the biceps, from beneath the anterior axillary fold to the middle of the bend of the elbow. The artery is *superficial* and *can be felt* throughout its entire length. The *outer shallower groove* extends up to the deltoid insertion and indicates the *position of the cephalic vein,* which above the deltoid insertion runs upward and inward along the anterior border of that muscle and then in the groove between it and the pectoralis major. The *deltoid insertion* is easily made out and is an important landmark, *indicating* the middle of the humeral shaft and the level of the insertion of the coracobrachialis, of the upper limit of the brachialis anticus, of the entrance of the nutrient artery on the inner surface, and of the point where the musculospiral nerve and superior profunda artery reach the outer border of the bone. The *shaft of the humerus* is so well covered by muscles that it can only be felt below the deltoid insertion, from whence the outer border can be traced down into the external supracondylar ridge.

Superficial Topography.—The course of the *median nerve* corresponds to that of the artery, lying external to it in the upper third, in front in the middle third, and internal in the lower third. The *internal profunda artery* is represented by a line from the inner aspect of the brachial artery at the middle of the shaft to the back part of the internal condyle. The *ulnar nerve,* following the brachial artery on its inner side, diverges from it at the middle of the shaft, with the inferior profunda artery, and follows a line from this point to the gap between the olecranon and the internal condyle. It may be felt along the back of the internal supracondylar ridge. The *musculospiral nerve,* with the superior profunda artery, follows a line from just below the junction of the posterior fold of the axilla with the arm downward, backward, and outward to the outer border of the humerus at the deltoid insertion, and thence downward to the front

of the external condyle, lying between the brachioradialis and the brachialis anticus in the lower fourth of the arm. The lower end of the groove external to the biceps corresponds to the superficial portion of the *musculocutaneous nerve*. The anastomotica magna is given off about 5 cm. (2 in.) above the bend of the elbow.

The Skin.—The skin of the arm is smooth and thin, especially anteriorly and laterally, where it is very free from hairs, so that it is here very suitable for skin flaps and for skin grafting. The point of insertion of the deltoid is free from muscular movement, so that the overlying skin is very well situated for vaccination, as it was formerly for the application of a seton. The skin is so *loosely attached* by the subcutaneous tissues to the deep fascia that in circular amputation it can be sufficiently drawn up by the traction of the hand, and requires no separate dissection to form a flap. If it requires any separation with the knife, it is only along the lines of the intermuscular septa. It is more loosely attached on the inner than on the outer aspect of the arm (*i. e.*, over the deltoid). The skin is readily stripped up in contused and lacerated wounds.

The Deep Fascia (*brachial aponeurosis*).—The deep fascia completely invests the underlying muscles to which it is loosely attached. It is *continuous* with that covering the elbow region below and with the fascia of the deltoid, the axilla, and the anterior and posterior axillary walls above. It is thin in front, where it covers the biceps, thicker behind. At the sides it is connected by the internal and external intermuscular septa with the internal and external borders of the bone. The *external intermuscular septum*, the weaker of the two, *extends* from the external condyle to the deltoid insertion, and is *perforated* by the musculospiral nerve and superior profunda artery about midway between the deltoid insertion and the tip of the external condyle. The *internal intermuscular septum extends* from the internal condyle to the teres major muscle (internal bicipital ridge), and is *perforated* by the ulnar nerve and the inferior profunda artery about 5 cm. (2 in.) above the internal condyle.

These two septa with the deep fascia divide the arm into *two compartments*, of which *the posterior contains* the triceps muscle with the upper part of the musculospiral and the lower brachial portion of the ulnar nerves and their accompanying vessels; *the anterior contains* the rest of the brachial muscles and soft parts. These compartments confine to a certain extent inflammatory or hemorrhagic effusions, which, however, can pass from one to the other by following the structures that pierce the septa. The *brachial aponeurosis* itself is *pierced* along the groove internal to the biceps by the internal cutaneous nerve about the middle and by the basilic vein a little below the middle of the arm, and along the external bicipital groove by the external cutaneous nerve, just above the elbow.

The Brachial Artery.—The brachial artery may be *ligated* in any part of its course. The *best guide* is the inner border of the biceps, which may overlap it in muscular subjects. Its changing relations with the *median nerve* (see above) should be remembered, but these are not always constant, so that this nerve is a poor guide. The number of cross-branches

between the two venæ comites sometimes embarrasses the operator. The *ulnar nerve* lies close to the inner side in its upper half, and may be mistaken for the median if the incision is too far internal. The musculospiral nerve is also behind the upper end of the vessel.

Anomalies occur more often in the brachial than in almost any other artery. The most *important anomaly* from a surgical standpoint is its *high division* (even in the axilla), in which case the smaller branch lies in front of and the other behind the median nerve. Hence if an artery is found in front of the nerve we should look for another behind it. Again, in the lower part of the arm the artery or one of its branches may deviate internally to pass to the inner side of the supracondylar process, with the median nerve. *Behind the artery* lies the coracobrachialis for a short distance, lower down the brachialis anticus. The *artery lies internal* to the humerus in its upper half or more, in front of it below; so that it *may be compressed* against the bone by pressure outward and slightly backward above, and directly backward below. Unless this pressure is applied carefully by the fingers, the median nerve can hardly avoid pressure, the result of which is the pain often complained of after the application of a tourniquet.

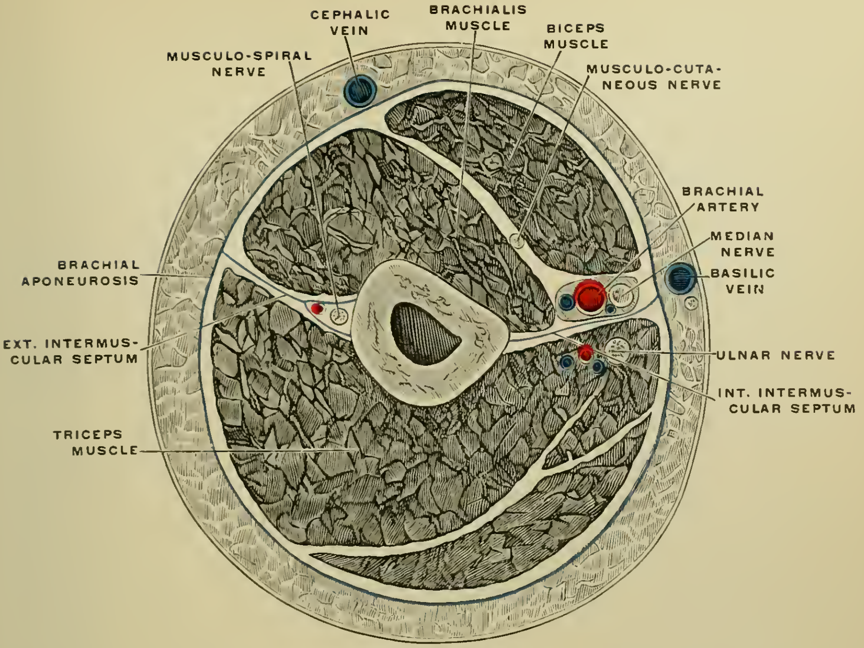
The Lymph Vessels.—The lymph vessels are largely superficial. Most of these (15 to 18) accompany the basilic vein, where they can readily be seen as a band of red striæ in lymphangitis. The most external stem usually accompanies the cephalic vein.

The Musculospiral Nerve.—The musculospiral nerve in its passage along the musculospiral groove is in close contact with the bone, and hence *may be injured* in contusions and wounds, and especially in fractures of the humeral shaft. It may also escape injury at the time of fracture, to be subsequently involved and *compressed in the callus.* In many cases an operation has become necessary to free it from the canal of callus or bone in which it is compressed. It has also been paralyzed by the pressure of the head resting upon the supinated and abducted arm in sleep. In the upper part, on the inner aspect of the arm, it is the nerve which most often suffers from *crutch paralysis,* the ulnar coming next in frequency. In all such cases there is pain and hyperesthesia along the course of the nerve and its branches if the nerve is merely irritated; paralysis and anesthesia if it is divided or severely compressed or stretched. The symptoms of paralysis resemble those in lead palsy, which also affects this nerve. The extensors of the wrist and fingers are paralyzed and "*wrist-drop*" is produced, indicating the inability of the extensors to extend the wrist. Owing to the above conditions the musculospiral is more often paralyzed than any other branch of the brachial plexus.

The *nerve* is most conveniently *exposed* after it has pierced the intermuscular septum *by an incision* following the anterior border of the brachioradialis, whose centre is opposite the point of perforation of the septum or midway between the deltoid insertion and the external condyle. It is sought for as it enters the cleft between the brachioradialis and the brachialis anticus. If it is to be exposed on account of injury in the musculospiral groove, the incision is carried upward along the posterior margin of the deltoid insertion.

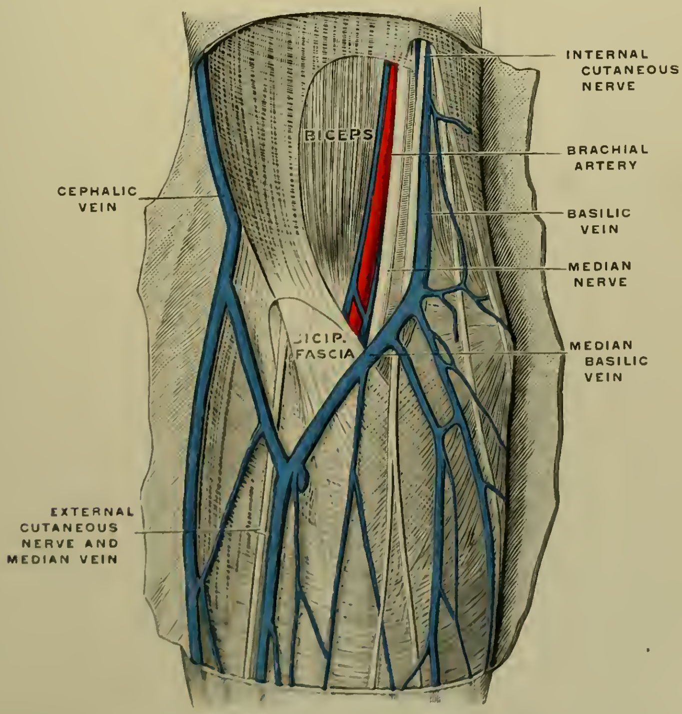
PLATE XVI

FIG. 69



Cross-section through the Middle of the Right Arm of a Female. Upper segment viewed from below. (Tillaux.)

FIG. 70



Front of Right Elbow. Superficial view. (Joessel.)

Fracture of the Shaft of the Humerus.—Fracture of the shaft of the humerus, or that part between the insertion of the pectoralis major and the upper part of the supracondylar ridges, is most often due to direct violence, sometimes to indirect violence. It is more often broken by *muscular action,* such as throwing a stone or the trial of strength known as "wrist turning," than any other bone in the body. The *displacement* is usually inconsiderable and depends largely upon the fracturing force and the line of fracture. Secondarily the muscles attached to the two fragments may have some effect upon their relative position. Thus the lower fragment is often drawn up by the biceps and triceps muscles, but the weight of the arm resists any considerable shortening. Theoretically in fractures above or below the deltoid insertion the lower or upper fragments respectively would be drawn outward by the action of the deltoid, but practically the displacement is usually independent of this action.

Delayed Union and Non-union.—Delayed union and non-union are of much more frequent occurrence in the humerus than in any other bone. Among the *causes* that lead to this may be mentioned (1) the *interposition* between the fragments *of muscular tissue* with which the bone is almost completely surrounded, the two fragments being driven into muscular masses on opposite sides of the bone; (2) the *defective immobilization* of the fragments due largely to the imperfect fixation of the joints above and below. According to Hamilton the flexed elbow soon becomes stiff by reason of muscular rigidity, so that the movement of the forearm imparts a movement to the upper end of the lower fragment instead of flexion or extension of the elbow. But this alone cannot account for the condition, for it would cause a greater movement of the fragments of fractures high up in the shaft, and non-union is more common in the middle third.

Amputation of the Arm.—*In the lower half* the *circular amputation* is best. The division and retraction of the skin has been already referred to. As only the biceps has no attachment to the bone, it retracts most and requires separate division a thumb's breadth below where the other muscles are divided, at the edge of the retracted skin. After division of the muscles and continued retraction of the soft parts the fleshy cone may again be divided at its base, at the level of the fully retracted skin.

Above the middle of the arm the biceps, long head of the triceps, deltoid, and coracobrachialis may all retract considerably and unequally, hence amputation by long anterior and shorter (one-half of anterior) posterior flaps has some advantages. The brachial artery should be in the posterior flap. The *principal arteries cut* are the brachial (with the median nerve), the superior profunda on the postero-external aspect (with the musculospiral nerve), and, in the lower half of the arm, the inferior profunda on the inner aspect (with the ulnar nerve). (Fig. 69.) In the flap method all the principal arteries divided are in the posterior flap. In the circular method the free retraction of the muscles and the active growth of the upper epiphysis before its union with the shaft at the age of nineteen (p. 183) is apt to result in a "conical stump."

To reach the humerus for removal of sequestra, etc., *incision* along the outer border is preferable, for the musculospiral nerve is the only structure which need be avoided.

THE REGION OF THE ELBOW.

The *limits* of this region may be arbitrarily assigned as two or three fingers' breadth above and below the "fold of the elbow." The elbow is *flattened* from before backward.

Surface Markings and Landmarks (Fig. 70).—*In front* are visible *three muscular elevations,* one on the outer side corresponding to the brachioradialis and the extensor group, one on the inner side corresponding to the pronator radii teres and the flexor group, and one in the centre corresponding to the biceps and brachialis. The two lateral elevations converge and meet below, enclosing between them a depression, *the cubital fossa,* into which the biceps tendon is felt to sink toward its insertion. From this fossa *two grooves* forming a V are continued upward along the two sides of the biceps tendon, to become continuous with the bicipital grooves of the arm. The details are distinct only in thin or muscular subjects. The *biceps tendon* is plainly felt, especially along its outer border, the inner border being continuous with the *bicipital fascia.* The "*fold of the elbow*" is a crease in the skin of the front of the elbow extending transversely between the two condyles, with a slight convexity downward. Hence it is some little way, 2 to 4 cm. ($\frac{3}{4}$ to $1\frac{1}{2}$ in.), *above the joint line.* It is obliterated in extension and not constant in position, so that it is not of great service as a landmark. It may be of some use, as employed by Malgaigne, to diagnosticate between an ordinary dislocation of the elbow and a supracondylar fracture of the humerus, the lower end of the humerus projecting below this fold in the former and the lower end of the upper fragment forming a prominence above it in the latter.

The **two condyles** are plainly felt, the inner and more prominent one even in conditions of extreme swelling. The outer condyle may be readily seen in semiflexion. The inner condyle points more or less backward. About 2 cm. ($\frac{4}{5}$ in.) below the more rounded external condyle the rounded *head of the radius* can be felt, especially on rotating the forearm. In extension of the elbow a marked depression on its posterior aspect indicates the position of the head of the radius and corresponds to the interval between the brachioradialis and the anconeus muscles. The two humeral *condyles* are *in the same transverse line* with one another and, when the arm is fully extended, with the uppermost part of the plainly felt *olecranon process.* When the elbow is flexed the tip of the olecranon comes to lie below the intercondylar line, so that when it is flexed to a right angle the interval is a little more than 2.5 cm. (1 in.). The intercondylar line is at right angles to the axis of the humerus. These relations are of great importance in differentiating dislocation from supracondyloid fracture, for in the latter case they are preserved, in the former they are altered.

Furthermore, in full extension the point of the olecranon is nearly in the same transverse vertical plane with the two condyles, while in dislocation it is displaced backward. The *olecranon* does not lie midway between the two condyles, but *nearer the internal condyle*, by 12 to 15 mm. ($\frac{1}{2}$ in.), so that the groove between the olecranon and the inner condyle is narrower as well as deeper than that between the olecranon and the outer condyle. Neither the coronoid process of the ulna nor the radial tubercle of the radius can be distinctly felt under ordinary conditions.

Topography.—The *joint line* of the elbow is only about two-thirds, 4 cm. ($1\frac{1}{2}$ in.), of the width between the condyles, and, while it nearly corresponds externally with the lateral limit of the condyle, its inner end is some distance, nearly 2 cm. ($\frac{3}{4}$ in.), external to the internal condyle. This partly accounts for the prominence of the internal condyle. The *line of the humeroradial joint* is horizontal and can be felt between the head of the radius and the external condyle; that of the *humero-ulnar joint* slopes obliquely downward and inward, so that the inner end of the trochlea is 1 cm. ($\frac{2}{5}$ in.) below the outer end. The obliquity of the humero-ulnar joint makes the *axis of the extended forearm* to diverge outward at an angle of 6 degrees, providing for the "carrying function" of the arm. It also makes the hand to be carried up toward the face in flexion, unless the forearm is supinated.

The Ulnar Nerve.—The ulnar nerve, lying in the deep and narrow depression between the olecranon and the internal condyle, is exposed to injury by pressure against its hard bed. *Pressure on it* gives the peculiar numbness and tingling of the ulnar side of the hand, etc., which is known as hitting the "funny bone." It was wittily remarked that it was so named because it bordered on the humerus. As the result of trauma or of congenital conditions the nerve may come to lie in front of the internal condyle or slip in front on flexion of the elbow. The congenital or idiopathic cases are far more numerous and seldom give rise to symptoms sufficient to require operation. The ulnar nerve is not confined to its groove in from 20 to 25 per cent. of cases. It is particularly important to *avoid it in excision* of the elbow by keeping close to the bone in its neighborhood. In a case of ankylosis of the elbow with much overgrowth of bone, due to a bad fracture, I have found the nerve in a bony canal.

The *musculospiral* nerve divides into the radial and posterior interosseous nerves just above and in front of the capitellum and may be injured in dislocations of the head of the radius.

The Brachial Artery.—The brachial artery *lies* in the inner of the two grooves in front of the elbow, just internal to the pearly white biceps tendon, which is an excellent guide to it, and rather more external to the median nerve. It *passes under* the *bicipital fascia*, where it *bifurcates* about 12 mm. ($\frac{1}{2}$ in.) below the centre of the bend of the elbow. It may be *compressed* by forcible flexion of the joint so as to diminish or even stop the radial pulse. Accordingly *aneurysms* here, more frequent in blood-letting days, have been treated by compression, by flexion of the elbow. In the fully extended position the artery is somewhat flattened beneath the bicipital fascia so as to lessen the radial pulse, or even to stop it in the

hyperextension possible with fracture of the olecranon or dislocation of the elbow. It has been ruptured by the forcible straightening of a stiff, bent elbow.

The Median Vein.—The median vein is joined by the deep median vein, thus receiving the blood of the deep veins of the forearm, and *divides into* the median basilic and median cephalic in the depression at the apex of the V (*cubital fossa*). The *median basilic vein crossing* superficial to the biceps tendon and fascia comes to *lie* in the inner groove where it joins the posterior ulnar vein a little above the internal condyle, forming thereby the basilic vein. Similarly the *median cephalic, passing* up in the outer groove, forms the cephalic vein by joining the radial vein about the level of the external condyle.

An M-shaped figure is thus formed by the veins in front of the elbow, but this typical arrangement is by no means constant, occurring only in about 50 per cent. of cases. But in almost all cases a communicating vein crosses the biceps tendon and fascia obliquely, and therefore overlies the brachial artery and median nerve, and this vein is usually large enough for venesection or intravenous infusion.

The *median basilic vein* or its substitute may *cross* the artery transversely or obliquely or it may run nearly parallel with it, in front of it, or to one side. Of all the veins in front of the elbow, the median basilic is usually *the largest,* the most prominent, the nearest the surface, and the one *least subject to variation.* Hence it was the one most often *chosen for venesection* in bloodletting days, and now is often chosen for intravenous infusion, in spite of the fact that it is separated from the artery beneath by the *bicipital fascia* only. This membrane, whose density depends upon the muscular development, is an excellent protection to the artery, but on account of the blind method of venesection formerly employed it is not strange that the artery was often wounded with the vein, giving rise to an arteriovenous aneurysm, an aneurysmal varix if the communication is direct, a varicose aneurysm if there is an intervening sac. The latter forms were more common at the elbow than anywhere else. The *median cephalic* is, therefore, safer, but with open exposure of the vein, as for intravenous infusion, it seems scarcely possible to wound the artery.

Of the *cutaneous nerves* at the elbow the *external cutaneous* passes behind the median cephalic vein, the anterior division of the *internal cutaneous* passes behind or (less frequently) in front of the median basilic. Hence the latter nerve or its branches may be wounded in opening the median basilic vein, an injury that, according to Tillaux, may lead to intense and chronic neuritis. Small twigs of the external cutaneous nerve may cross in front of the median cephalic vein, and the injury to these branches, or possibly the main nerve behind the vein, or their inclusion in the scar may lead, according to Mr. Hilton, to a reflex contraction of the elbow, "bent arm," due to the contraction of the biceps and brachialis muscles which are supplied by its main trunk, the musculocutaneous. He has cured the condition by resection of the scar, which was found to have included some of the nerve filaments.

PLATE XVII

FIG. 71

Left Elbow. Anteroposterior. Arm extended and supinated. Male, aged thirty years.

The *superficial lymphatics* accompany the veins, lying in front of them, and are most numerous on the antero-internal aspect of the elbow. Situated in front of the upper part of the internal condyle is the *epitrochlear lymph group* (1 to 4 in number). The lowest node is the most constant, is termed *the epitrochlear node*, and is the lowest node in the upper limb. It may become inflamed in any injury or inflammation of the hand and forearm, especially of its ulnar side, from whence its afferent vessels come. It is not infrequently enlarged and palpable in the early adenopathy of syphilis. Around the elbow-joint is an *extensive and free anastomosis* between branches of the superior and inferior profunda and the anastomotica magna, from the brachial above, and branches of the anterior and posterior ulnar, posterior interosseous, and radial recurrents from the ulnar, interosseous, and radial arteries below. This anastomosis provides a *collateral circulation* in case of ligature of the lower half of the brachial or in aneurysm at the elbow.

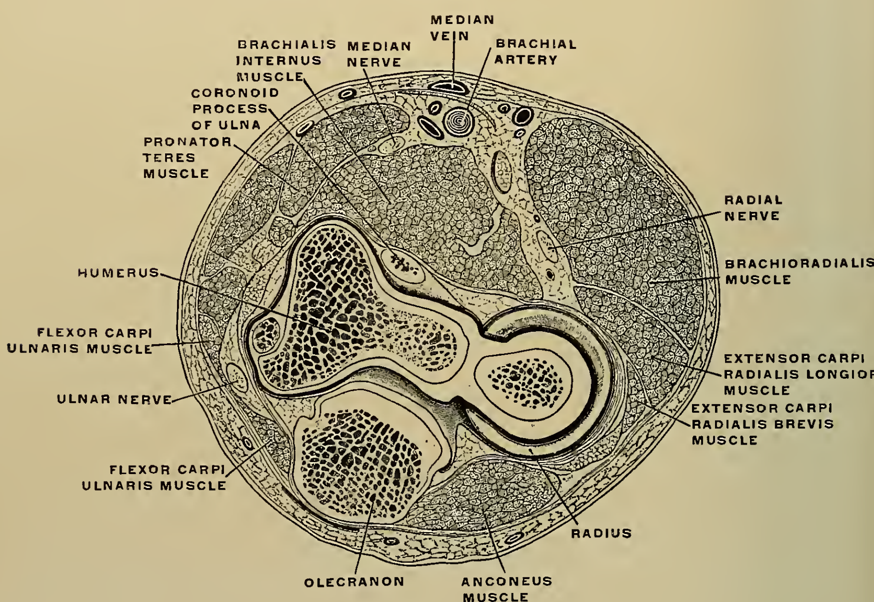
The Skin.—The skin about the elbow is thin and fine in front, where it is readily excoriated by tight bandages or poorly applied splints; it is thicker and less sensitive behind. Although the thin skin in front allows the veins to be clearly seen through it, yet in subjects with much subcutaneous fat it may be difficult or impossible to see them. Between the skin and the olecranon is a *subcutaneous bursa*, not infrequently the seat of the accumulation of serum or pus from a *bursitis* or of blood from an injury. Occupations involving pressure on the elbow favor bursitis here, of which "miner's elbow" is an example.

The Elbow Joint.—The elbow joint *depends for its strength* largely upon the shape and relation of the bones forming it, reinforced by the overlying muscles and the lateral ligaments. Only flexion and extension are permitted; the presence of *lateral motion* shows that the ligaments are torn, stretched, or softened, as in dislocation or tuberculous disease, and hence is *a sign of some lesion* of the joint. The *internal lateral* is the strongest and *most important ligament* of the elbow, and, as it resists lateral strain as well as limits flexion and extension, it suffers most often in sprains and dislocations. Its attachment to the entire inner border of the great sigmoid cavity of the ulna prevents the wide separation of the fragments in fracture of the olecranon, for part of it is attached above and part below the line of fracture. The *anterior and posterior parts* of the capsule are the weakest, especially the posterior portion, which presents two pouches, one on either side of the olecranon. As this is also the most superficial part of the joint, the **effusion in joint disease** is first noticed as a *fluctuating swelling here*. The line of the *radiohumeral joint* and the depression seen behind it in extension also show some swelling at an early stage, and here, or in the pouches on the sides of the olecranon, especially the external one, the joint may be aspirated or injected. Beneath the brachialis a deep-seated bulging of the thin anterior part of the capsule is also observed in effusion into the joint. Normally the joint surfaces are in contact in all positions, but if the soft parts are divided the radius and humerus separate by a slight interval when the capsule is incised, readily allowing the knife to enter the joint in exarticulation.

In case of *suppuration* in the joint the *capsule is likely to give way* at its weakest point, *posterosuperiorly.* The pus thus comes to lie between the triceps and the humerus, burrows between them and points at either border of the muscle, especially the outer. In other cases it may perforate the thin anterior ligament beneath the brachialis and point near the insertion of the latter, especially on the outer side on account of the presence of the bicipital fascia internally.

The *diseased elbow* is usually *held in* a position of *semiflexion,* a position assumed when the joint is forcibly injected (Braune), for in this position it holds the most fluid. In disease, however, the position is probably *due to a reflex contraction* of the biceps and brachialis muscles, supplied by the musculocutaneous, which is the principal nerve of the joint. Owing

Fig. 72



Cross-section at elbow.

partly to the accurate coaptation of the ulna and humerus, *ankylosis* of the elbow after injury or disease is *not uncommon.* Sudden forcible straightening of an ankylosed elbow entails some danger of rupture of the brachial artery at the bend of the elbow. If the elbow is ankylosed in a straight or semiflexed position, the ankylosis should be broken up or the elbow excised, for in this position the arm is not only useless but in the way.

Excision of the Elbow Joint.—In excision of the elbow joint the *three most important muscles* in relation to it, which act on it and therefore *must be preserved,* if possible, are the biceps, brachialis, and triceps. The insertions of the first two are readily preserved. The ulna may be divided low enough to remove the entire coronoid process without sacrificing the

PLATE XVIII

FIG. 73

Backward Dislocation of the Elbow.

insertion of the brachialis into the tuberosity at its lower end. The usual *incision* is a *posterior longitudinal* one *through the triceps*, which is then separated from the olecranon on either side of the incision by longitudinal cuts close to the bone (subperiosteally), in order, as far as possible, to leave the triceps insertion connected with the periosteum of the bone below the point of section. The strong expansion from the outer margin of the triceps tendon should always be saved, as it enables the triceps to retain a hold on the forearm. In freeing the parts about the internal condyle great care should be taken to *avoid injury to the ulnar nerve* lying behind it, by making whatever incisions are necessary close to bone and longitudinal. The nerve should not be seen. Another nerve in some danger of injury when the upper end of the radius is being bared is the posterior interosseous as it winds around the radius in the supinator muscle. It is wise to *remove 5 cm.* (*2 in.*) *of bone* (including both humerus and forearm bones) to avoid the danger of re-ankylosis.

In connection with excision in young subjects under seventeen (when the lower humeral epiphyseal line ossifies) it may be noted that the *principal growth in length of the humerus* occurs *at the upper end.* Most of this lower epiphysis and the upper radial epiphysis are within the joint and may be the starting point of joint disease or secondarily involved by it.

Dislocation of the Elbow—Dislocation of the elbow is more *common* than that of any single joint save the shoulder. It is most common (85 per cent.) *in the first twenty years* of life, when, according to Krönlein, it is the equivalent injury of dislocation of the shoulder by indirect violence.

Dislocation of both bones of the forearm backward is the *typical form*, being by far the most common. It is usually *due* to a fall on the outstretched hand, by which the elbow is *hyperextended* and *often abducted.* It is only in hyperextension that the beak of the olecranon presses against the bottom of the olecranon fossa. It then serves as a fulcrum so that by continued hyperextension the ulna is torn as it were from the humerus. The internal lateral ligament is thereby torn, generally at its insertion into the humerus, the external lateral ligament is usually torn or detached from the humerus, and the rent extends across the thin anterior ligament. The lateral ligaments oppose hyperextension and lateral motion, and are the strongest bonds holding the bones together. Hence when they are torn the violence continuing forces the coronoid process far enough backward to allow it to be pushed up behind and above the trochlea, opposite to or into the olecranon fossa.

Associated Injuries.—The *orbicular ligament* is rarely injured, and a partial preservation of the external lateral ligament may affect the attitude of the limb, adducting it, and render reduction difficult. The *brachialis* is stretched, sometimes lacerated and rarely torn across. The *biceps* is rendered tense and occasionally slips around the outer condyle. The *median and ulnar nerves* may be greatly stretched. The *tip of the internal condyle* is often torn off and may be displaced upward and backward with the internal lateral ligament. A common lesion of practical importance is the *stripping up of the periosteum* at the *back of the external*

condyle, often continuous with the external lateral ligament and the capsule behind the radius. If the dislocation remains long unreduced, so that the periosteum is held away from its place of attachment, new bone is here produced which interferes with the extension of the elbow by impinging on the radius. As *complications* there may be *fracture* of the coronoid process, olecranon, head of the radius (partial or complete), and the shaft or lower extremity of the radius.

Symptoms and Signs.—*The crucial signs, on which alone the diagnosis should rest*, are the relative positions of the two condyles, the olecranon and the head of the radius, as determined by palpation. The *olecranon* is *displaced* backward and upward, the backward displacement being more marked in flexion, the upward in extension. The *head of the radius* can be *felt* and perhaps *even seen* under the skin behind the external condyle and to the outer side of the olecranon. In addition the elbow is usually flexed at an angle of about 135 degrees, but may be extended or even hyperextended, and the lower end of the humerus causes a *fulness in front* (below the crease of the elbow). When viewed from in front the *forearm appears shortened* in front and broadened above, its *axis* may be deviated to either side, flexion and extension are limited and painful, and *lateral motion exists*.

Reduction is often accomplished by flexion and traction, commonly using the knee in the bend of the elbow as a fulcrum and to produce traction. In this method the coronoid process has to pass down behind and then below the trochlea, and to do this the ulna must be separated from the humerus by more than 12 mm. ($\frac{1}{2}$ in.), the height of the coronoid process. This can only occur when the laceration of the ligaments and soft parts is extensive, or, as often happens, is made so by the process of reduction. It also requires simultaneous elongation of the muscles of the front and back of the arm, so that their relaxation by anesthesia greatly facilitates the reduction. Forcible pronation may also facilitate it.

A method more in line with the principle that a dislocated bone should be returned along the route by which it was displaced with the least possible additional rupture of the soft parts, is the method by traction upon the extended or hyperextended forearm, followed by flexion of the elbow or by direct pressure forward on the upper end of the radius and ulna and backward pressure on the lower end of the humerus. In this method force is applied only in a position (hyperextension) in which the arm was forced in being dislocated, and no new damage is done to the ligaments and soft parts.

As to the varieties of dislocation at the elbow it may be noted: (1) That both bones are more often dislocated together than separately, for the radius and ulna are connected by powerful ligaments, the radius and humerus are not. (2) That antero-posterior displacements are much more common than lateral ones on account of the lateral width and the anteroposterior narrowness of the joint, the absence of lateral movement and the presence of anteroposterior movement, the feebleness of the anteroposterior ligaments and muscular support, and the strength of the lateral ligaments and the support afforded by the lateral muscles. (3)

That the rarest dislocation of both bones is forward, for it is resisted by the large strong olecranon process. (4) That if but one bone is dislocated, it is most often the radius, for it is less strongly connected with the humerus and more exposed to indirect violence through the hand.

Dislocation of the radius alone *may occur* in the forward, backward, or outward direction, named in the order of frequency. In **luxation of the radius forward** the head of the bone *arrests flexion* of the elbow at or near 90 degrees by impact upon the humerus. It is usually due to falls upon the hand while the elbow is probably hyperextended and to traction upon the forearm probably combined with extreme pronation. The *elbow* is slightly flexed and often abducted, and the forearm is almost always pronated. *Reduction* may usually be accomplished by traction combined with supination, adduction, and direct pressure upon the head of the radius, but it is sometimes resisted or recurrence favored by the interposition of a portion of the capsule between the head of the radius and the capitellum.

Dislocation of the radius by elongation, or the *"subluxation of the radius of young children,"* is an injury *quite common* between the ages of one and three, less common up to six, and is *due* to forcible traction on the extended elbow, possibly combined with adduction, as in lifting a child or holding it when it stumbles.

Symptoms.—The child cries with pain, refuses to use the elbow, which is slightly flexed; the wrist is pronated, and there is tenderness over the head of the radius. Passive motion is free except for supination. The *injury consists in* the escape of the anterior portion of the radial head below the orbicular ligament, and is *readily reduced by* forcible supination with pressure backward on the head of the radius followed by flexion of the elbow. It is sometimes spoken of as a sprain of the elbow, and has also been thought to be a dislocation of the triangular fibrocartilage in front of the lower end of the ulna (Goyrand).

Luxation of the ulna alone is usually backward, but may very rarely be forward or inward. Although all kinds of dislocations of the elbow have been described as *complete or incomplete,* the differences are often inconsiderable and unimportant. Incomplete forms are more liable to occur in the lateral than in the anteroposterior varieties.

Fractures of the Lower End of the Humerus.—Fractures of the lower end of the humerus are much more *common* than those of the upper end or of the shaft, and are *more common in young subjects* than in adults. Various forms occur, rendering a differential diagnosis necessary and often difficult.

A. **Supracondyloid Fractures.**—Supracondyloid fractures, or fractures through the expanded portion above the condyles, are *due to violence,* acting, as a rule, through the bones of the forearm, as in a fall upon the hand, *pressing the lower end of the humerus* (1) *backward,* by the partly flexed forearm or possibly by hyperextension ("extension fractures"); (2) *forward* from behind ("flexion fracture"); or (3) *inward* ("adduction fracture"). In (1) the line of fracture is oblique from behind downward and forward, the common form; in (2) it is oblique in the opposite direc-

tion; and in (3) it is oblique from above and externally downward and inward. Form (3) is found especially in children and the line of fracture is low down on the inner side. Forms (1) and (2) may be transverse or oblique from side to side. The character and extent of the *displacement* vary with the direction of the fracture.

In the *common form* (1) the *lower fragment* with the bones of the forearm is *displaced,* and sometimes tilted, backward and upward by the original violence, aided perhaps by the triceps, biceps, and brachialis muscles. Hence the sharp lower end of the upper fragment projects forward, and the *deformity resembles a dislocation,* from which it may be *distinguished* by the relative position of the two condyles, the olecranon and the radial head (see above, p. 194), and by the fact that the displacement is readily reduced and as readily recurs. The *displacements to avoid in the treatment* are overriding and a lateral angular one in the position of adduction (*cubitus varus*). The latter is due to the support of the elbow by the sling, which should only be beneath the wrist, and perhaps to muscular action or a primary displacement in an "adduction fracture"—form (3). If the fracture heals in the adducted position the axis of the forearm may be in line with that of the arm, or it may form an angle with it whose apex is directed outward (cubitus varus). The carrying function of the arm is thus lost. The overriding is corrected by traction and its recurrence is prevented by the weight of the arm and by anterior and posterior moulded plaster splints.

B. **T-shaped or Intercondyloid Fracture.**—A T-shaped or intercondyloid fracture may be like the supracondyloid form with the addition of a vertical fracture running through the thin portion of the bone between the condyles into the joint. But as they are commonly due to great violence the bone is often much comminuted and the fractures run in various directions, the *essential fracture* being a *separation of both condyles from each other and from the shaft.* On theoretical grounds the longitudinal ridge of the sigmoid cavity has been thought to act as a wedge in producing the vertical fracture into the joint. The thinness of the bone above the trochlea, due to the presence of the olecranon and coronoid fossæ, favors the occurrence of such a fracture. The artery or nerves about the joint may be torn or compressed in this or the preceding variety, but less frequently than might be expected.

For surgical purposes the terms epitrochlea and epicondyle are applied to those portions of the internal and external condyles (respectively) which are outside of the joint capsule.

C. **Fracture of the Epitrochlea.**—Fracture of the epitrochlea often *accompanies dislocation* of the elbow, when it is probably due to avulsion by traction of the forearm flexor muscles, or it may be *due to direct violence* from behind. The *displacement* may be downward and forward in the direction of the muscles attached to it, but the dense periosteo-aponeurotic covering and the attachment of the internal lateral ligament prevent much displacement if the fragment is small. In cases occurring with dislocation it is commonly displaced upward and backward. The epitrochlea is a *distinct epiphysis* which joins the shaft at about the age of

eighteen, and before this age *may be separated* from the shaft instead of fractured. The ulnar nerve lying behind it has been injured in a few cases of fracture of this process.

D. **Fracture of the Epicondyle.**—Fracture of the epicondyle is *rare,* if it ever occurs, and many deny the possibility, owing to its small size.

E. **Fracture of the Internal Condyle.**—Fracture of the internal condyle is usually *due* to a fall on the flexed elbow or to forced ad- or abduction of the forearm. The *line of fracture* extends from the inner border of the epitrochlea, or the ridge above it, downward and outward through the outer part of the trochlea, or even beyond it. The ulna is attached to the fragment, and *much displacement* of these two is *prevented* by the attachment of the former to the radius, unless this is dislocated, as occasionally happens. A *late lateral displacement* in the adducted position (cubitus varus) may occur in this as in supracondyloid fractures, from the same cause (see p. 202), and should be guarded against. The relative position of the epitrochlea and the tip of the olecranon is preserved, and their displacement with reference to the epicondyle is generally too slight to be recognized.

F. **Fractures of the External Condyle.**—Fractures of the external condyle are *more common* than those of the internal condyle and are *especially frequent in the young.* They are *due to* a fall on the hand when the elbow is flexed or upon the inner and back part of the flexed elbow or to forcible adduction of the forearm. The *line of fracture* runs from the supracondylar ridge above the epicondyle downward into the joint usually to the groove of the trochlea, coinciding in part with the epiphyseal line. In children it is likely that this form of fracture often consists of a separation of the capitellar epiphysis, usually combined with the splitting off of a small piece from the outer side of the diaphysis. As the fragment is attached by ligaments to both the radius and the ulna, the *displacement* is *usually slight,* but there is a tendency to tilting (flexion) and sometimes to rotation of the fragment. As in fractures of the internal condyle, so also in fractures of the external, there is independent mobility of the condyle, usually with crepitus, abnormal lateral mobility, and pain on transverse pressure and at the point where the fracture crosses the supracondylar ridge. An essential and sometimes difficult feature of the treatment is the reduction of the displacement. In both forms, even with satisfactory reduction of the displacement, the range of motion may be diminished by callus obstructing the olecranon or coronoid fossa, etc.

G. **Separation of the Lower Epiphysis.**—Separation of the lower epiphysis, as a whole, is rare and improbable, except at an early age, on account of its irregular outline. The portion comprising the united epiphyses of the radial condyle, capitellum and trochlea unite with the shaft in the seventeenth year,and that portion which includes the capitellar and epicondylar nodules is not infrequently separated in the elbow injuries of children (see above, F). The epitrochlea unites about the eighteenth year. In cases where the diagnosis is certain the fracture has often been compound and the displacement of the lower fragment (usually backward) considerable.

H. **Fracture of the Olecranon.**—Fracture of the olecranon is commonly thought to be *due to* a fall upon the elbow. It is probably not due to direct violence alone, but the olecranon is firmly held by the triceps while the patient falls upon the forearm, and the ulna is bent about the trochlea as a fulcrum. Hence the *line of fracture* is most often near the weakest point, the constriction at the middle of the process. The *epiphysis* of the olecranon, which unites with the shaft in the sixteenth year, comprises only the summit of the process, and is very rarely separated.

The *upper fragment* is *seldom much separated* by the action of the triceps, as it is *held to the lower fragment* by the extension of the triceps insertion, the internal lateral ligament, and its own aponeurotic attachments, which are usually untorn. The olecranon cannot be drawn by the triceps above the position it occupies in extension of the elbow, the olecranon fossa, unless the ligaments that bind it to the humerus are torn, which very rarely happens. In fact, whatever separation there may be is rather due to the descent of the lower fragment in flexion of the elbow. The *repair* is, as a rule, *by fibrous union*. I have found the fragments separated by a blood clot so that they could not be approximated without its removal.

I. **Fracture of the Coronoid Process.**—Fracture of the coronoid process is *very rare* except as a *complication of* backward *dislocation* of the ulna or of both bones of the forearm. In a case of this kind, owing to its tilting forward and interfering with flexion of the elbow, I was obliged to remove it. It cannot be caused by the action of the brachialis, as the latter is inserted into the ulna at the base of the process rather than into the process itself.

J. **Fracture of the Head or Neck of the Radius.**—Fracture of the head or neck of the radius is *rare*. Fracture of a *part of the head* is sometimes observed in dislocation of the elbow. I have observed two cases where a notch could be felt on rotation of the radius, and the fragment was felt in close proximity but could not be replaced, and was removed in one case.

THE FOREARM.

This region *extends* from the region of the elbow to two fingers' breadth above the radial and ulnar styloid processes (Joessel). It is *conical* in form, *flattened* from before backward, especially in muscular subjects, more rounded in women, children, and non-muscular subjects on account of the accumulation of fat in front and behind and the slight development of the lateral muscles. On account of its conical form circular amputation without splitting of the skin flap is not appropriate for the upper two-thirds of the forearm.

Surface Markings and Landmarks.—The *ulna* can be *felt*, along its posterior border, the entire length of the posterior surface of the forearm. In muscular subjects its position is marked by a groove external to which is an elevation, extending from the back of the external condyle down the middle of the posterior surface, formed largely by the extensor communis.

Separated from this by a groove is another prominence on the outer aspect of the forearm, formed by the brachioradialis and the two radial extensors of the wrist. The upper fleshy part of these muscles covers the *radius* so that its upper half cannot be felt. But in the lower half of the arm its lateral surface can be felt, though less plainly than the ulna, for it is covered by the tendons of the two radial extensors of the wrist, and about 5 cm. (2 in.) above the radial styloid process it is crossed by the extensors of the thumb, which form a slight ridge directed obliquely downward, outward, and forward. On the anterior surface of the supinated arm in thin subjects two slight furrows can be seen, one from the middle of the bend of the elbow to a point just internal to the radial styloid process, the other from the internal condyle to the radial side of the pisiform bone. These two furrows represent respectively the *course of the radial and the lower two-thirds of the ulnar arteries*, along which one *incises to ligate them.* They also represent the anterior borders of the brachioradialis and the flexor carpi ulnaris respectively. The *course* of the *upper third of the ulnar artery* is represented by a line, slightly convex inward, from the middle of the bend of the elbow to the junction of the middle and upper thirds of the line indicating the course of the rest of the ulnar artery.

The Skin.—The skin of the forearm is thin and movable and the surface veins show through it unless the subcutaneous fat is abundant. It is to be noted that over the middle of the posterior surface, especially in its upper part, there are almost no veins and only very small nerves, and that this is the aspect of the limb most exposed to injury. The **fascia**, which in the upper half of the forearm is closely attached to the muscles, is free from the tendons in the lower half and attached to the posterior borders of the ulna and radius, so as to incompletely divide the forearm into *two compartments* with the aid of the interosseous membrane.

Arteries.—The free *anastomoses* between the radial and ulnar arteries are to be remembered in wounds of either vessel. *In ligating* either vessel by an incision along the lines just given, it is to be noted that the *sheath of the radial* is connected with that of the pronator radii teres, in the upper half of the forearm, and the *sheath of the ulnar* with that of the flexor profundus, upon which it lies, so that to freely expose these arteries the sheaths of these two muscles must be divided. Also *in ligating* the ulnar artery in the lower two-thirds of the arm the *ulnar nerve* is almost necessarily *exposed* on its ulnar side, while in ligating the radial artery the *radial nerve* is *not exposed*, as it lies farther to the radial side and is connected with the sheath of the brachioradialis. Among the **arterial anomalies** of practical interest may be mentioned: (1) The perforation of the deep fascia by the *radial artery* in the middle or lower third of the forearm and its *subcutaneous course* around the wrist to the back of the first interosseous space; it can be easily injured in its subcutaneous portion, and if the radial pulse is sought in its usual place it is weak, being furnished by the smaller superficialis volæ branch. (2) In case of a *high origin* of the *ulnar artery*, from the axillary or brachial, it usually pierces

the fascia and becomes superficial a little above the elbow, and thence, passing under or sometimes over the bicipital fascia, its *course* in the upper third of the forearm is *superficial*, covered by the fascia, as a rule, but sometimes not.

Skeleton of the Forearm.—Of the two bones, the **ulna** is the stronger and extends farther above, the **radius** below, and the two are most nearly of equal strength about the centre of the limb. In all parts the two bones are *nearer the posterior* than the anterior aspect, and especially so in the upper part. They are nearest the centre of a section of the limb in the lower end of the middle third. On account of the posterior position of the bones, especially the ulna, they are best examined or reached for excision on this aspect; also fractures are most readily compounded posteriorly. The two bones approach one another above and below and are separated in the middle, the separation being widest a little below the middle of the forearm. In *supination* both bones are *parallel*, in *pronation* they are *crossed*. The *interosseous space* is narrowest in pronation, widest in supination, and almost equally wide midway between pronation and supination, hence the latter position is maintained in most fractures of the forearm. In pronation and supination the *ulna remains stationary*, the radius revolving around it describes a section of a cone whose apex is above in the centre of the radial head and the base below. *Supination is the stronger* of the two movements; thus in using a screw-driver, gimlet, or cork-screw the main force is applied during supination. In ordinary pronation and supination there is some flexion and extension of the elbow and rotation of the shoulder in addition to rotation of the radius. The *oblique ligament* helps to hold the radius in contact with the humerus through the medium of the ulna. The *obliquity of* the fibers of the *interosseous membrane* (from above and without downward and inward) makes the ulna share with the radius in the strain of the latter in resting on or pushing with the palm, and communicates to the radius the force imparted to the ulna in a blow from the shoulder.

Fractures of the Shafts of the Radius and Ulna.—Fractures of the shafts of the radius and ulna may be *due* to direct, indirect, or rarely to muscular violence. *Fracture of the ulna alone*, the more superficial and exposed of the two bones, is almost invariably the result of *direct violence*, such as a fall upon the ulnar side of the forearm or a blow on the arm raised to protect the head, for in this position the ulna becomes uppermost. *Fracture of the radius alone* is also generally due to direct violence, but is more often the result of indirect violence than fracture of the ulna, for it receives all shocks transmitted from the hand. According to Malgaigne, "*green-stick fractures*" are more common in the forearm than elsewhere.

The *displacement* varies greatly with the direction of the fracture and the fracturing force, so that we may find overriding, lateral or angular displacement. In some cases it is *affected by muscular action*. Thus in fracture of the radius alone above the insertion of the pronator teres the upper fragment may be fully supinated by the biceps and supinator (brevis), while the lower fragment is maintained by the splints in the

usual position midway between supination and pronation. If union occurs with the fragments in these relative positions, the power of *supination will be lost* as the supinators can act no farther. A similar result may follow after fractures of both bones. Another important *displacement* that may be *due* partly or entirely to *muscular action* in fracture of one or both bones between the two pronators is that in which the two *bones approach one another.* The upper fragments of both bones, or of the radius alone, may be drawn toward the opposite bone by the pronator teres; and the lower fragments of both or either bone may be similarly made to approach the opposite bone by the pronator quadratus and the brachioradialis. The resulting *diminution of the interosseous space* or the actual *osseous union* between the two bones interferes with or entirely prevents rotation of the radius, for the performance of which the interosseous space is essential. Excessive formation of callus may produce a similar result, and angular displacement is its most frequent cause. In the latter case the radius of rotation is increased at the apex of the displacement in the radius, and full supination is prevented by the interosseous membrane, for to become fully supinated the angle in the radius must move farther from the ulnar than normally. Actual bony union of the two bones, which is very rare, is more likely to occur when both bones are broken at the same level, but, as a rule, the radius is broken nearer the elbow than the ulna.

The upper fragment of the radius may also be drawn forward by the biceps and pronator teres. In general, when only one bone is broken the other acts as a splint to prevent marked displacement, except the rotary (supination) displacement of the radius and the approach of one or both fragments to the opposite bone. In fracture of the ulna alone marked displacement of its fragments may occur in case of the not infrequent complication of dislocation of the head of the radius forward.

Treatment.—In treatment the following points should be observed after the *displacement is corrected* as perfectly as possible, for this is of the utmost importance to preserve function. If there is any *tendency to supination* of the upper fragment of the radius, the forearm should be placed in the supine position, so that after union the power of supination may be preserved. In order *to avoid* as far as possible the *union of the two bones,* and the consequent loss of rotation, the forearm should be placed in a position in which the interosseous interval is wide, *i. e.,* in the position midway between pronation and supination. The position of complete supination would serve best, for in it the interval is widest, but it is more irksome to the patient. With the object of preventing union between the two bones the use of graduated pads have been advised to force the bones apart by pressure. But this pressure, as well as any undue pressure of the splints and bandages, is in danger of producing *gangrene* of the limb, which is more common after fracture of the forearm than after fracture elsewhere. This is owing to the fact that most of the venous blood is returned by the surface veins, which, as well as the main arteries, are readily affected by pressure. This pressure of the forearm is also liable to produce *ischemic paralysis* and contraction of the muscles

which occur mostly in the forearm and nearly destroy the usefulness of the hand. The tendency to overriding, which may be maintained by the tension of the muscles, may be largely overcome by flexion of the elbow and of the wrist, which relaxes these muscles.

Amputation of the Forearm.—In amputation of the forearm the *flap method* is best suited to the *upper two-thirds,* the *circular* to the *lower third.* In the latter part the soft parts are mostly skin and tendons and the bones come closer to the sides of the limb, so that the flap method is unsuitable. As the soft parts divided are mostly tendons they are more easily and cleanly divided from within outward by transfixion. *Arteries and nerves divided:* (Fig. 74.) On the sides of the anterior or flexor aspect of the cut surface are the radial and ulnar arteries, the former no longer accompanied by its nerve, the latter with the ulnar nerve to its inner side. In front of the interosseous membrane is the anterior interosseous artery, and with the median nerve, in the posterior layer of the sheath of the flexor sublimis, is the median artery, sometimes of large size. Posteriorly between the deep and superficial layers of muscles are the posterior interosseous nerve and artery.

In the *upper two-thirds* of the arm, where the muscular masses cover the bones at the sides and the limb is more flattened and conical, *amputation by anteroposterior flaps* is more suitable. The *anterior flap contains* the brachioradialis and the flexor muscles, the *posterior flap* the extensor muscles. The anterior flap is more substantial, as the bones lie nearer the posterior surface. The *radial artery,* with the radial nerve on its radial side, runs the whole length of the anterior flap and is *cut* near its outer border, internal to the brachioradialis. The *ulnar artery* is *cut* at a higher level, in front of the ulna and between the superficial and deep flexors. The anterior interosseous artery is cut short just in front of the interosseous membrane, the posterior interosseous is cut long between the superficial and deep muscles. The principal *nerves* are good *guides to the corresponding vessels,* except the ulnar nerve in the upper third.

It may be noticed in this connection that the ulnar artery gives off the interosseous trunk 2.5 cm. (1 in.) below the bifurcation of the brachial, which occurs opposite the upper part of the neck of the radius. As the chief pronators are the pronators teres and quadratus and the flexor carpi radialis, and the chief supinators are the biceps and supinator (brevis), it follows that in amputation above the insertion of the pronator teres (the middle of the forearm) the radius will become supinated and its further rotation lost.

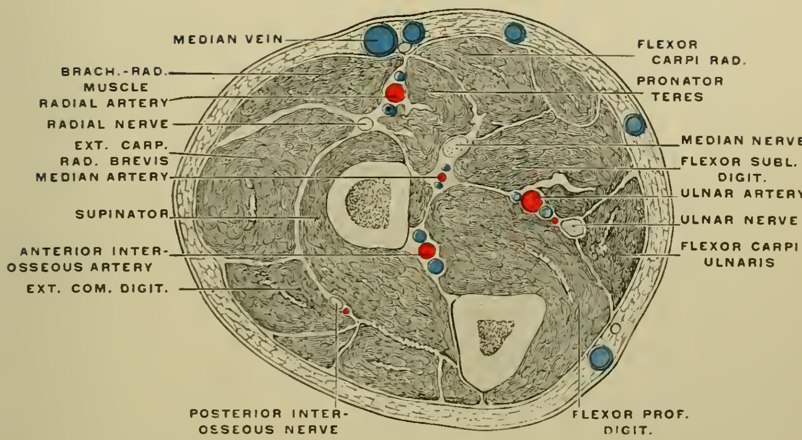
THE REGION OF THE WRIST.

This region may be artificially *limited,* according to Tillaux, by planes two fingers' breadth above and below the radiocarpal joint.

Surface Markings and Landmarks.—The *radial and ulnar styloid processes* can always be made out and are the most important landmarks

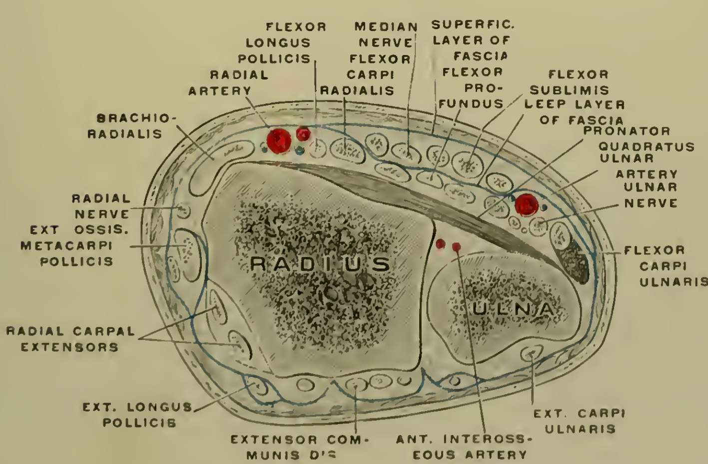
PLATE XIX

FIG. 74



Cross-section of Right Forearm at Lower End of Upper Third. Proximal side of section, from below. (Joessel.)

FIG. 75



Cross-section of Right Wrist, 1½ cm. above Articular Surface. Upper segment of the section. (Tillaux.)

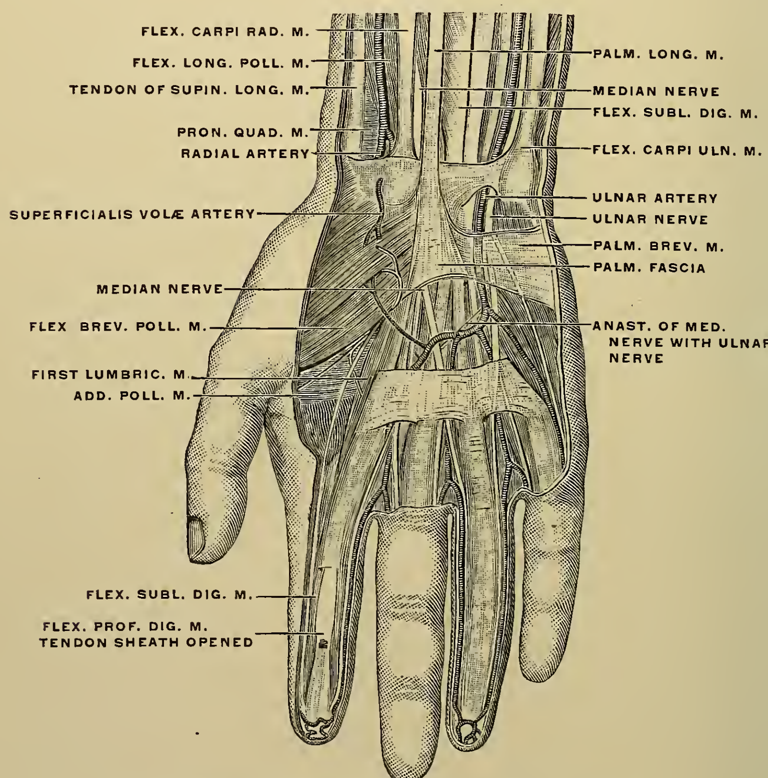
for examination of or operations on the wrist. The *radial styloid* process, a finger's breadth above the thenar eminence, is more anterior and descends nearly 12 mm. ($\frac{1}{2}$ in.) lower than that of the ulna. Partly on account of this fact abduction is less free than adduction of the hand. In the female the *x*-rays show that position of the articular surface of the radius as compared with that of the ulna is decidedly lower than in the male (Stimson). The radial styloid is commonly *carried upward in Colles' fracture* so as to be on a level with or above the ulnar styloid, a point of diagnostic importance (Fig. 79). Just beneath the radial and ulnar styloid processes one enters the *radiocarpal joint, the line of which* is concave inferiorly and rises 1 cm. above that connecting the styloid processes. In pronation of the forearm the *ulnar styloid process* is less distinct and the bony prominence at the back of the ulnar side of the wrist is due to the head of the ulna. The ulnar styloid process is most plainly felt in supination, at the inner and posterior aspect of the wrist, to the inner side of the extensor carpi ulnaris tendon.

In front of the wrist are several *skin creases,* of which the *lowest and most distinct* is slightly convex downward and is about 1 cm. ($\frac{2}{5}$ in.) below the radiocarpal joint (Tillaux). If the *line of this crease* is continued around the back of the wrist it *crosses* the neck of the os magnum in the line of the third metacarpal bone. This point is felt as a depression in extension of the wrist, but is replaced by a prominence, the head of the os magnum, in flexion of the wrist. This crease also *indicates* fairly well the *upper border* of the *anterior annular ligament,* which corresponds to the lower border of the posterior annular ligament. Above both the thenar and the hypothenar eminences is a slight depression, which in Colles' fracture forms a marked angular depression and serves as an excellent sign of this injury (Tillaux). Extending downward from the point where the flexor carpi radialis tendon crosses the lower skin crease a bony *ridge* can be felt, formed by the *tubercle of the scaphoid* and the *ridge of the trapezium.* Corresponding to this level at the base of the hypothenar eminence the *pisiform bone* can be still more readily felt. Below the head of the ulna at the back of the wrist the *cuneiform bone* may be felt as a slight prominence.

Topography.—The Front of the Wrist (Fig. 76).—On the radial side in the groove between the tendons of the brachioradialis and flexor carpi radialis, which is most marked when the wrist is semiflexed, can be felt the *radial artery.* This is very *superficial,* lying just beneath the fascia, and hence easily exposed, compressed, or wounded. It is here that the *pulse* is taken and arterial sclerosis looked for. It continues down to a point just below the styloid process. To the ulnar side of the flexor radialis tendon is the *most prominent tendon* of this region, that of the *palmaris longus.* It is made most prominent when the wrist is partly flexed, the thenar and hypothenar eminences adducted and the fingers extended. It is near the centre of the wrist. In the groove between the two last named tendons, or beneath the tendon of the palmaris longus, is the *median nerve* covered by the deep fascia. As the palmaris longus is not seldom wanting, the *flexor carpi radialis tendon* is the better guide to the

nerve, which lies between it and the flexor sublimis. On the ulnar side the *flexor carpi ulnaris* can be felt extending to the pisiform bone. It is made most prominent by slight flexion of the wrist and adduction of the little finger. In the groove to its radial side, between it and the more deeply placed flexor sublimis tendons, lie the *ulnar artery and nerve,* the latter close to the ulnar side of the artery. The artery and nerve are covered by a deep and a superficial layer of the deep fascia of the forearm, but pierce the deep layer, which is connected with the sheath of the flexor

Fig. 76



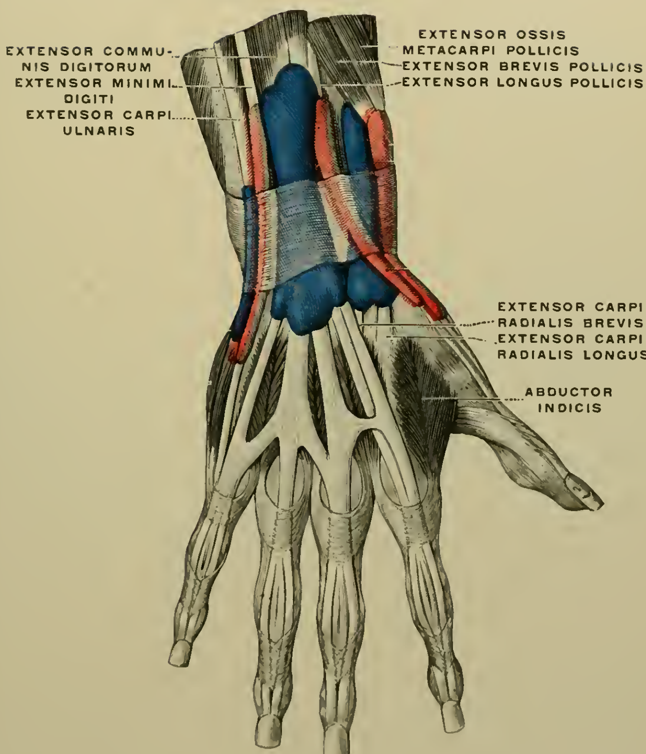
Palmar aspect of right hand. Superficial layer. (Joessel.)

sublimis, just above the anterior annular ligament, in order to pass in front of the latter. The *synovial sheath* for the superficial flexors and that for the long flexor of the thumb extend up the wrist above the annular ligament for 3 to 3.5 cm. (1¼ to 1½ in.) (Fig. 82). The structures above named at the front of the wrist lie upon or in front of the pronator quadratus muscle.

At the **outer aspect of the wrist** the *outer surface of the radius* is *crossed by* the tendons of the extensor ossis metacarpi pollicis and extensor brevis pollicis. These tendons are made very prominent by extension and abduction of the thumb, in which position they bound externally a

PLATE XX

FIG. 77



Synovial Membranes of Tendons on the Dorsum of the Forearm and Hand, artificially distended. (Gerrish, after Testut.)

depressed triangular space, the "*snuff-box space*" or "tabatière anatomique" of French writers, whose ulnar boundary is formed by the extensor longus pollicis tendon. The *floor of the space* is *formed by* the scaphoid and trapezium with their dorsal ligaments, over which, and beneath the above tendons, runs the *radial artery* in its course from just below the apex of the styloid process to the back of the first interosseous space. The artery is here *covered by* two layers of fascia, the deeper of which holds it close to the carpal bones. Subcutaneously the radial vein and branches of the radial nerve cross this space, the latter vertically, so that *incisions* to reach the artery should be *made vertically*. The *tendons* which cross the outer and dorsal surfaces of the lower end of the radius *occupy grooves bounded by ridges*, of which that on the radial side of the groove for the extensor longus pollicis is prominent subcutaneously. The groove for this tendon indicates the centre of the combined dorsal and external surfaces of the radius, and corresponds about to the interval between the scaphoid and semilunar bones. Between the two grooves for the extensors of the thumb is one, sometimes subdivided by a low ridge, for the short and long radial extensors of the wrist.

On the **dorsal surface of the wrist** on the ulnar side of the extensor longus pollicis is a shallow groove for the extensor communis and extensor indicis, next to this, and between the two bones is a groove for the extensor minimi digiti and between the head and styloid process of the ulna is a groove for the extensor carpi ulnaris.

The order and relations of the *tendons* at the wrist are given in detail, as they are not infrequently severed in wounds and *require tendon suture*, for which an accurate knowledge of their position and relations is essential, though when necessary the distal part of a tendon may be grafted into another muscle or tendon with good results.

The *six grooves*, for the tendons at the back and outer side of the wrist, are *converted into* as many *osseo-aponeurotic canals* by the *posterior annular ligament*, which binds down the tendons and prevents their displacement in hyperextension of the wrist. This ligament is continuous with and a thickening of the fascia of the dorsum of the forearm and hand. In these six canals the *tendons* are *surrounded by synovial sheaths* (Fig. 77). *The sheaths* of the three carpal extensors and the extensor ossis metacarpi pollicis *extend* to or nearly to the insertion of their tendons; that of the extensor indicis is very short; the sheaths of the other tendons extend a varying distance onto the dorsum of the hand, from the upper border to the middle of the metacarpus. All *the sheaths begin above* near or a little above the upper border of the annular ligament.

The sheath of the extensor ossis metacarpi and the extensor brevis pollicis is the one most often inflamed in the so-called *tenosynovitis crepitans*. This is accompanied by swelling, pain, and crepitation on motion, and is due to injury or unusual use of those muscles, gout, exposure, etc. These tendons and tendon sheaths are liable to adhere to the bone, etc., and to each other after Colles' fracture, and cause stiffness of the wrist and fingers.

The Wrist Joint.—The *strength* of the radiocarpal, or wrist joint, *depends upon* the number of *strong ligaments and tendons* that surround it, the absence of a long lever on its distal side and the nearness of the numerous small bones and joints of the hand among which movements and shocks are distributed. *Its movements* are largely supplemented by those of the mediocarpal joint. In the wrist joint proper extension is most free, and its *strongest ligament is the anterior* which limits hyperextension. It is noteworthy that the commonest injury is received during forced extension, for in falls one naturally falls upon the palm, the wrist being extended, rather than upon the dorsum of the hand, the wrist being flexed. The *dorsal ligament* is so *thin and superficial* that swelling is first noticed at the back of the wrist in effusion into the joint. In *disease of the joint* the latter is held midway between flexion and extension, as the tendons at the front and back are about equally strong. If the wrist joint is injected one notices, especially on the dorsum, little hernial protrusions of the synovial membrane, from which are derived most of the **ganglia**, or "weeping sinews," which are so common in this situation. At first these communicate with the joint, but, as a rule, this communication becomes obliterated as the pedicle becomes lengthened. This pedicle may often be followed by dissection as a fibrous cord connecting the ganglion with the surface of the joint capsule. Similar protrusions are to be found on the synovial sheaths of the tendons, but these are much less often the starting point of ganglia.

Dislocations of the Wrist.—Dislocations of the wrist are not common, for in the common form of violence, due to a fall on the palm, the joint is protected by the strong anterior ligament, and fracture of the lower end of the radius almost invariably results. The dislocation is *usually backward,* less often forward, of the carpus on the forearm. It is usually *due to great violence,* and hence is *often compound* and sometimes complicated by rupture of tendons or fracture of the styloid processes or of adjacent bones. "Barton's fracture," or the chipping off of the posterior edge of the articular surface of the radius, may occur in backward dislocations. I have seen a compound backward dislocation in which the semilunar bone projected forward through the anterior wound, and was almost entirely detached. Both forms of dislocation may be due to violence applied to the flexed or extended wrist. The *deformity* of *backward dislocation* closely *resembles that of Colles' fracture,* but in the former the swelling in front of the wrist extends farther down and ends more abruptly; that at the back of the wrist is more sharply outlined at its upper border. In addition the hand is usually more flexed and less movable in dislocation.

In the **inferior radio-ulnar joint** the *triangular fibrocartilage* is the principal ligament and the strongest ligamentous connection between the two bones. The synovial cavity of this joint is usually separate from that of the radiocarpal joint. *Dislocation* of this joint, apart from that sometimes observed in connection with Colles' fracture, is *rare.* It is usually forward or backward of the ulna. In the latter form it is usually due to exaggerated pronation, so that the hand is pronated and supination is

PLATE XXI

FIG. 78

Normal Wrist. Adult Male.

FIG. 79

Recent Colles' Fracture. Comminution. Male, aged forty-five years. (Stimson.)

interfered with. The forward form has been due to direct violence acting upon the two bones in opposite directions while the hand is supinated. The wrist may be pronated or supinated, and rotation is difficult and painful. The *ulna is prominent* at the front or back of the wrist according to the form of dislocation. Some surgeons have thought that the injury described above (p. 201) as subluxation of the head of the radius in young children is a dislocation of the lower end of the ulna.

Colles' Fracture.—Colles' fracture is one through the lower end of the radius from 12 to 25 mm. (½ to 1 in.) above its articular surface, at or near the point where the compact tissue of the shaft joins the cancellous tissue of the lower extremity of the bone, which appears to be a weak spot. It is *one of the commonest fractures,* and is most frequent in the elderly. The *direction* is transverse, often with a slight obliquity upward and backward and sometimes with a moderate slant upward and outward. The lower fragment sometimes shows a moderate backward *displacement,* and there is usually considerable backward and often some outward rotation. Thus the articular surface looks downward and backward instead of downward and forward as normally. The x-rays show that the displacement is less than commonly supposed, and that the typical deformity may be present when the displacement is slight, being due to the swelling of the soft parts. *Impaction* of the upper fragment into the cancellous tissue of the dorsal and lateral part of the lower is the rule, and *comminution* of the lower fragment is frequent. In addition, *the ulnar styloid* process may occasionally be fractured by avulsion, by means of the internal lateral ligament rather than by the fibrocartilage.

The **deformity** in typical cases is *characteristic.* The prominence on the dorsum over the lower fragment, due to its backward displacement and rotation and to swelling, gave origin to the name "*silver fork fracture,*" given by Velpeau, on account of the resemblance of its outline as seen from the radial side. The end of the *ulna is very prominent in front* on account of the displacement upward, backward, and somewhat outward of the lower fragment of the radius with the carpus, which preserves its relations with it. The prominence in front over the lower end of the upper fragment is mostly due to swelling of the soft parts. The *radial styloid is displaced* up to or above the level of the ulnar styloid and the transverse creases in front of the wrist are deepened. Crepitus and abnormal mobility are not present in cases with marked impaction and may not be easily recognizable in other cases.

The *cause* of Colles' fracture is almost always a fall upon the palm of the hand. The **mechanism** is neither simple nor constant, and has been and still is a much disputed point. (1) The fracture is due to a crushing of the cancellous tissue between the carpus and the shaft, the weight of the body being received in the long axis of the radius while it is within 30 degrees of the vertical. (2) The axis of the radius being more oblique and not in line with the fall, the force is decomposed, part of it passing up the shaft in the long axis of the radius and part acting transversely to break the bone at its weakest point. The backward rotation and displacement of the lower fragment indicates the direction of this latter

part of the force. (3) The fracture is due to a cross-strain exerted on the lower end of the radius through the strong anterior ligament, made tense by hyperextension of the hand. The bone is broken by avulsion on the principle that a stout ligament is stronger than cancellous bone, so that the latter gives way first. Most fractures are probably produced in one or the other of the first two ways. There is no doubt that it can be and sometimes is produced by avulsion. This theory rests upon experiments on the cadaver, and is supported by many French and German writers on surgical anatomy (Tillaux, Joessel, etc.).

Epiphyseal separation is probably more often due to this mechanism. The *epiphysis joins the shaft* in the twentieth year; it *includes* the insertion of the brachioradialis and the facet for the ulna. The *line* of the epiphyseal cartilage is *nearly horizontal* and may be intrasynovial internally. Arrest of growth of the radius has followed epiphyseal separation in young subjects.

Complete reduction of the displacement in Colles' fracture is often difficult, but is essential to prevent permanent deformity and to insure perfect function. In some cases, especially in adults, complete reduction of the deformity is impossible on account of the crushing and comminution. In such cases some permanent shortening of the radius and prominence of the ulna is inevitable. In spite of such persistent moderate displacement the function of the wrist may be very good. Retention is easy after reduction.

Amputation at the Wrist Joint.—Amputation at the wrist joint is *rarely performed.* Its principal *object* is to save the movements of pronation and supination. In most cases of injury it will either be necessary to amputate higher or it will be possible to save more, even a finger, which is most desirable. In cases of disease the necessary skin covering is involved and the movements of rotation are often lost from the disease. In general, amputations in which the bones are left covered with cartilage are objectionable, as the latter has almost no reparative action. The *elliptical method,* resembling that by a long palmar flap, *is the best.* In it the cicatrix is dorsal, the stump is covered by the tough and well-nourished tissues of the palm, and the styloid processes are well covered. The great tendency to *retraction of the skin on the dorsum,* due to the looseness of the subcutaneous tissues, should be remembered. Disarticulation is easier from the dorsum. The *radial artery* is *cut* at the outer end of the dorsal wound, the *ulnar* at the inner and the *superficialis volæ* at the outer part of the palmar flap.

Excision of the Wrist.—Excision of the wrist includes the removal of the carpal bones and usually the articular ends of the bones of the forearm and metacarpus. As the joints are covered and protected by strong tendons which move the wrist and fingers and which (save those of the palmaris longus and flexor carpi ulnaris) are surrounded by synovial sheaths, the *incisions* are planned so as to spare these tendons and their sheaths as far as possible. Including that of the pisiform, there are *seven separate synovial sacs* in the joints of the wrist and carpus. It is *important to spare* the radial artery, which is close to the first carpometacarpal

joint (dorsally), the deep palmar arch (see p. 220), and if possible the annular ligaments. In *Ollier's method the dorsoradial incision* is along the radial border of the extensor indicis tendon, between it and that of the extensor longus pollicis, the *ulnar incision* is along the inner side of the extensor carpi ulnaris tendon. The pisiform bone may usually be left, and the trapezium should be when possible. Unless the subperiosteal method is employed, and this is often difficult, the tendons of the extensors and flexors of the carpus are severed or detached. *Another simple and satisfactory method* is to split the hand between the second and third metacarpal bones, between the trapezoid and os magnum, and between the scaphoid and semilunar bones, by an *incision* between the extensor indicis and the extensor communis tendons. Since the more general use of the *x*-rays, fracture of the carpal scaphoid has been found to be not uncommon. The fracture passes through or near the middle third of the bone and the central fragment is not infrequently dislocated, usually backward. Stiffness, with abduction, of the wrist and tenderness in the *tabatière* are the common symptoms. If a fragment is dislocated it should be removed.

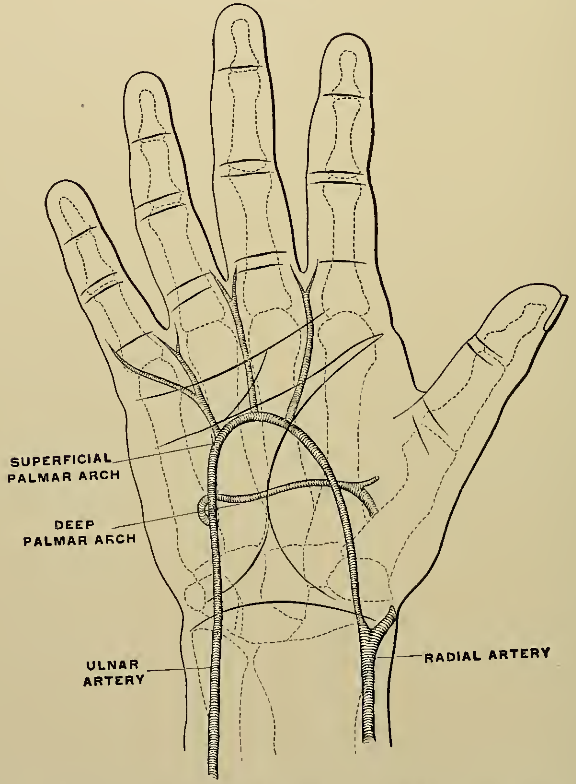
THE HAND AND FINGERS.

Surface Markings and Landmarks.—**Palmar Surface.**—Between the *thenar eminence* on the radial side and the *hypothenar eminence* on the ulnar side is the "*hollow of the hand*," a concavity of a somewhat triangular outline. Its apex is above and it is limited below by three little elevations opposite the clefts between the fingers. These elevations are due to the projection of the fatty tissue between the flexor tendons and the overlying digital slips of the palmar fascia, which form the grooves between these elevations. The hollow of the hand is more marked in muscular subjects and when the fingers are flexed and the eminences adducted. The bony prominences at the proximal ends of the thenar and hypothenar eminences have already been referred to.

Three of the many **creases** in the skin *of the palm* deserve notice. **The first** marks off the thenar eminence from the hollow of the palm. It starts at the wrist near the middle line and ends at the radial border of the palm at the base of the first phalanx of the index finger. **The second** starts on the radial border, at or just below the last, and crosses the palm obliquely inward and upward to the hypothenar eminence. **The third** and lowest starts from the elevation opposite the cleft between the first and second fingers and runs obliquely inward and upward to the ulnar border. The *first is due* to the opposition of the thumb, *the second to* the flexion at the metacarpophalangeal joint of the index and middle fingers, *the third to* the similar flexion of the inner three fingers. **Topographically,** *the second fold*, where it crosses the third metacarpal bone, is just below the lowest point of the superficial palmar arch, and *the third fold* crosses the necks of the metacarpal bones, roughly indicates the upper limit of the synovial sheaths of the middle and ring fingers, and lies a little above the division of the palmar fascia into its digital slips. The *metacarpophalangeal joints* lie about midway between this fold and the webs of the fingers.

The uppermost of the *folds across the front of the fingers* separate them from the palm, and are on a line with the webs of the fingers and 12 to 15 mm. ($\frac{1}{2}$ in.) below the metacarpophalangeal joints. The upper of the middle series of folds are opposite the first interphalangeal joints and the lowest set of folds are 2 to 3 mm. above the second interphalangeal joints. *On the thumb* the two creases correspond to the two joints, the upper crease crossing the joint obliquely.

Fig. 80

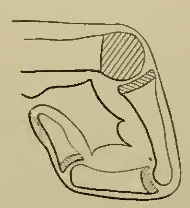


Position of the principal creases of the palmar surface and of the palmar arches.

Dorsal Surface.—The proximal ends of the first and fifth metacarpal bones are prominent and can be readily felt. A line slightly concave downward, joining the upper ends of these and 1 cm. ($\frac{1}{2}$ in.) below the lowest skin crease in front of the wrist, indicates the *line of the carpometacarpal joints.* When the fingers are flexed, the *prominences of the knuckles* are formed by the distal ends of the proximal bone of each joint (Fig. 81), so that the joint line lies below the prominences by 2 mm. ($\frac{1}{12}$ in.) in the distal, 4 mm. ($\frac{1}{6}$ in.) in the middle, and 8 mm. ($\frac{1}{3}$ in.) in the proximal joints. The first dorsal interosseous muscle forms a prominence between the first and second metacarpal bones when the thumb is adducted.

The Skin of the Palm.—The skin of the palm and of the palmar surface of the fingers is *thick* and dense and without hairs or sebaceous glands. Beneath the epidermis, which is particularly thick, small *subepidermal abscesses* not infrequently develop. Beneath the thinner skin of the distal phalanges the fibro-fatty layer forms the "pulp" of the finger, which lies directly upon the periosteum. The *skin of the dorsum* of the hand is much thinner, and down to the second or third phalanges is supplied with numerous hairs and sebaceous follicles, and hence is liable to furuncles and other lesions associated with these structures. The *skin of the palm* is more abundantly supplied with *sweat glands* than any other part of the body, four times more so, according to Sappey. Hence the profuse perspiration that may occur here, as is well known. The Pacinian bodies and tactile corpuscles in connection with the abundant cutaneous nerve supply are more numerous on the palmar aspect of the fingers than elsewhere in the body. The palmar aspect of the third phalanx, especially that of the index finger, is *most sensitive*, and, with the exception of the tip of the tongue, possesses more acute tactile sensibility than ony other part. *The dorsum* of the hand, on the contrary, has *but little tactile* sensibility. The area around the upper end of the nail is liable to superficial subepidermal abscesses (*"run around," paronychia*), which develop quickly. The spaces beneath and around the nail and the various glands of the skin render sterilization of the hand more difficult than that of most parts of the body.

Fig. 81



Outline to show the relation of the bent knuckles to the joint lines. The shaded portions represent the epiphyses.

The Subcutaneous Tissue.—The subcutaneous tissue on the palmar aspect intimately connects the overlying skin with the underlying fascia in the palm, and with the tendon sheaths in the fingers. Hence subcutaneous inflammatory or bloody extravasations and edema are practically impossible here, while *on the dorsum*, where the subcutaneous tissue is *lax and abundant*, swelling and edema may be very marked. For the same reason skin *wounds* do not gape on the palmar surface, but gape widely on the dorsum. The denseness of the skin and underlying tissues on the palm renders inflammation very painful on account of the tension caused by the inflammatory products, while on the dorsum the reverse is the case. Another particular in which the *coverings of the palm resemble the scalp* is in the arrangement of the subcutaneous fat, the lobules of which are contained in small fibrous compartments of the subcutaneous tissue. This arrangement of the skin and underlying tissues of the palm *adapts it to resist* the effects of *pressure and friction*. Thus the ulnar border of the palm is much used in resting on the hand and in hammering movements, and it is also noteworthy that the soft parts here are singularly free from large nerves. The entire palmar aspect is singularly *free from large surface veins*, which are abundantly found on the dorsum of the hand. The *lymph vessels*, on the contrary, are more numerous on the palmar surface of the hand and fingers.

The Palmar Fascia.—The palmar fascia, *in its central portion* beneath the hollow of the palm, is very *dense and thick* and is *triangular* in form. *Its upper end* is connected with the lower border of the annular ligament and receives the insertion of the palmaris longus, of which it is sometimes regarded as the degenerated distal end. Its lower end or *base splits into four slips,* which are inserted into the skin at the bases of the fingers and send fibers to the fibrous tendon sheaths of the fingers and the superficial transverse ligaments. The digital vessels and nerves and the lumbricales muscles emerge in the interval between these slips. The denseness of the fascia well protects the soft parts beneath.

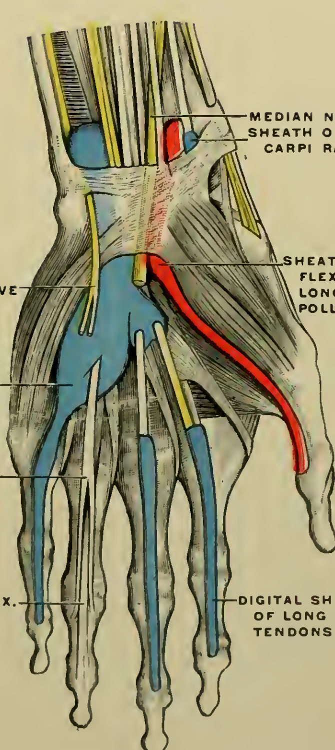
Dupuytren's contracture is a peculiar *contraction of the palmar fascia* and its slips, especially those going to the *ring and little fingers.* It usually begins about opposite the metacarpophalangeal articulation and extends in both directions. It occurs especially in men after middle life, and may be associated with traumatism. It gradually flexes the first, then the distal, and finally the second phalanges onto the palm. The tendons are not involved, but between them and the thickened projecting cord-like slips of fascia, which are connected with and wrinkle the skin, is a layer of fatty connective tissue.

Laterally the palmar fascia is continued as a thinner layer over the thenar and hypothenar eminences. A fibrous membrane connects the deep surface of the palmar fascia, on each side of the central portion, with the interosseous fascia covering the palmar interossei. In this way *two lateral* (thenar and hypothenar) *and a central compartment* are formed in the palm. Suppuration commencing in any of these spaces may be limited to that space for a time, but the membranous septa are thin and may soon yield. The *central compartment is continuous above,* beneath the annular ligament and along the flexor tendons, with the wrist and forearm. *It is continuous below with* the sheaths of the flexor tendons and the three intervals between the digital slips of the fascia, which correspond to the webs between the fingers. Hence *pus in the central compartment* of the palm makes its way up into the forearm or down along or between the fingers. The resistance offered by the palmar fascia is so firm that rather than perforate it pus makes its way through the interosseous spaces to the dorsum, though this course is resisted by a layer of fascia covering the deep palmar arch and the interossei muscles. This deep fascia joins the membranous septa separating the central compartment of the palm from the thenar and hypothenar compartments in front of the third and fourth metacarpal bones respectively.

Practically **abscesses of the palm** may be divided into those in front of and those behind the palmar fascia. *Abscesses in front of the fascia,* whether subepithelial or subcutaneous, are small, confined to the palm, and very painful; but the pain is limited to the palm, movement of the fingers is not very painful, and there is no tendency to extend to the wrist or to cause swelling of the dorsum unless it occurs in the areas just above the interdigital clefts. *Subfascial infection* or *abscess* may spread to the fingers, wrist, and forearm by following the flexor tendons, or to the dorsum after perforating the interosseous fascia. The dorsum is usually

PLATE XXII

FIG. 82



Tendon Sheaths and Muscles of the Palmar Surface of the Left Hand. (Joessel.)

much swollen. Pointing of such abscesses may also occur just at or above the clefts of the fingers. The pain is intense, is felt along the course of the nerves, and is increased by movements of the fingers. In *opening abscesses of the palm* and in all operations on the palm *the incision* should be *vertical,* parallel with the tendons and digital nerves, and above or below the superficial palmar arch (see p. 197). If an *incision* is required *in the wrist* it should be vertical, and if made on the ulnar side of the palmaris longus tendon it will avoid the ulnar and radial arteries and the median nerve.

The **fibrous sheaths of the flexor tendons** *extend* from the metacarpo-phalangeal joints to the upper ends of the last phalanges at the insertion of the flexor profundus tendons. There being no intervening fascia in the fingers, the skin and subcutaneous tissues are connected with these sheaths in the same intimate way as with the fascia in the palm. The fibrous sheaths arch across the front of the phalanges between their lateral margins and thus form semicylindrical canals which lodge the synovial sheaths. The fibrous sheaths are dense and rigid, so as to remain open when cut, so that in amputation of the fingers an open channel, leading up to the palm, is left for the spread of infection. Opposite the joints of the fingers the sheaths are thin and lax, leaving spaces between their obliquely decussating fibers, through which the synovial lining may protrude and suppuration may find its way into the interior of the sheath.

Synovial Sheaths.—Two synovial tendon sheaths are found in the palm, *the outer* for the flexor longus pollicis, *the inner* for the superficial and deep flexors of the fingers. These *extend* up beneath the annular ligament, where they are constricted, and for about 3 cm. ($1\frac{1}{4}$ in.) above it into the wrist. Inferiorly the outer one extends to the insertion of the flexor longus pollicis, the inner one to the insertion of the flexor profundus of the little finger, and to about the middle of the metacarpal bone for the other three fingers, but farther down on the tendons of the ring finger than on those of the other two. On the ring, middle, and index fingers the *digital synovial sheaths* commence opposite the heads of the metacarpal bones and extend to the insertion of the profundus tendons, being contained within the fibrous sheath (Fig. 82). They are thus separated by 12 to 25 mm. ($\frac{1}{2}$ to 1 in.) from the main palmar synovial sheath of the flexor tendons. Hence operations on and inflammation of the thumb and little finger are more serious than of the other fingers, for inflammation in the former may more readily spread to the main synovial sacs, causing a swelling of the palm, which is constricted beneath the annular ligament and is expanded again in front of the wrist, "hour-glass shape." This is seen, not infrequently, in case of felon of these two fingers. As the two sacs may communicate normally or pathologically, inflammation may spread from the thumb to the little finger, or vice versa, giving rise to a horseshoe-shaped swelling. The two palmar sacs may be the seat of cysts which show their characteristic form. In case of tuberculous inflammation here, and in the sheaths of the extensor tendons at the back of the wrist, the sheaths are often filled with fibrinous masses known as rice bodies. The tendons within their synovial sheaths do not lie free,

but are connected with them by synovial folds, like mesenteries, which contain the nutrient vessels and may be ruptured in severe sprains, causing an effusion in the sac. In the digital sheaths these folds are almost wanting.

The Superficial Palmar Arch (Figs. 76, 80).— The superficial palmar arch *lies* beneath the palmar fascia and superficial to the flexor tendons. Its *course* is represented by *a line,* slightly convex downward, commencing at the radial side of the pisiform bone and crossing the palm in line with the palmar aspect of the thumb when abducted at right angles with the index finger. This line should be *avoided* if possible *in incisions* in the palm. The **deep arch** (Fig. 80) *lies* about 12 mm. ($\frac{1}{2}$ in.) nearer the wrist, in front of the bases of the metacarpal bones, and beneath the deep or interosseous fascia. It is nearer the dorsal than the palmar surface and is more liable to injury from the former side. The *bifurcation of the digital arteries* occurs about 12 mm. ($\frac{1}{2}$ in.) above the webs of the fingers.

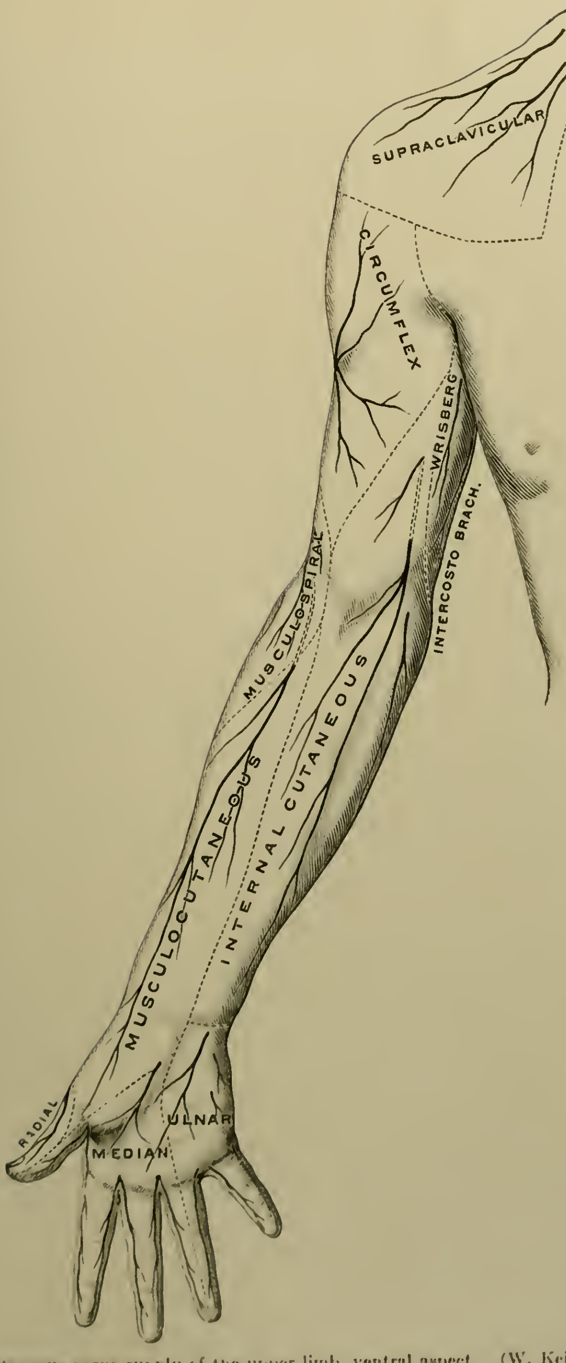
The *blood supply of the fingers* is very *abundant,* the pulp of the fingers being one of the most vascular parts of the body. It is owing to this fact that in so many cases the tip of the finger, accidentally cut off, has grown on again when reapplied at once.

Wounds of the palmar arches and their branches are serious on account of the *difficulty of checking the hemorrhage.* This is due to the danger of damaging important structures of the palm and to the free anastomoses, whereby ligature of either the radial or ulnar or both does not control the bleeding, for the arches anastomose with each other and with the carpal arches, which communicate with the two interosseous vessels above. Hence the two ends of the divided artery should be secured if possible, but if the wound is deep or narrow, pressure may often arrest the bleeding. The possibility that pressure may cause gangrene, owing to the rigidity of the parts, should be borne in mind.

Beneath the superficial arch and superficial to the flexor tendons is the **median nerve** in the groove between the long flexor of the thumb and the flexors of the fingers (Figs. 76, 82). The **nerve supply** of the hand and fingers is of interest and practical importance.

Cutaneous Nerve Supply (Figs. 83 and 84).—*Palmar Surface.*—The palm is *supplied by* the median and ulnar nerves which anastomose with one another. The palmar aspect of the little finger and the ulnar side of the ring finger are supplied by the ulnar, that of the other fingers by the median. **On the dorsum** of the hand the radial and ulnar nerves *supply* its radial and ulnar sides respectively, and anastomose with one another. The dorsal aspect of the thumb is supplied by the radial nerve, as is that of the index and the radial side of the middle finger, as far as the second phalanx. The dorsal branch of the ulnar nerve supplies the dorsal aspect of the little, ring, and ulnar side of the middle fingers as far as the second phalanx. In some cases the contiguous halves of the dorsum of the first phalanx of the ring and middle finger is supplied by the radial nerve or partly by the radial and partly by the ulnar. The dorsal aspect of the second and third phalanges of the four fingers are supplied by branches from the nerves supplying their palmar surfaces.

FIG. 83



Cutaneous nerve supply of the upper limb, ventral aspect. (W. Keiller.)

The occasional apparently contradictory results of nerve lesions are partly due to the above-mentioned variation (on the ring and middle fingers) and to the anastomoses between the nerves on the dorsal and palmar surfaces of the hand. Thus the loss of sensation is often quite slight in comparison with the area supplied, and the same facts, and not "immediate union," probably help to explain the cases where sensation has returned within a few hours after suture of one of the nerves.

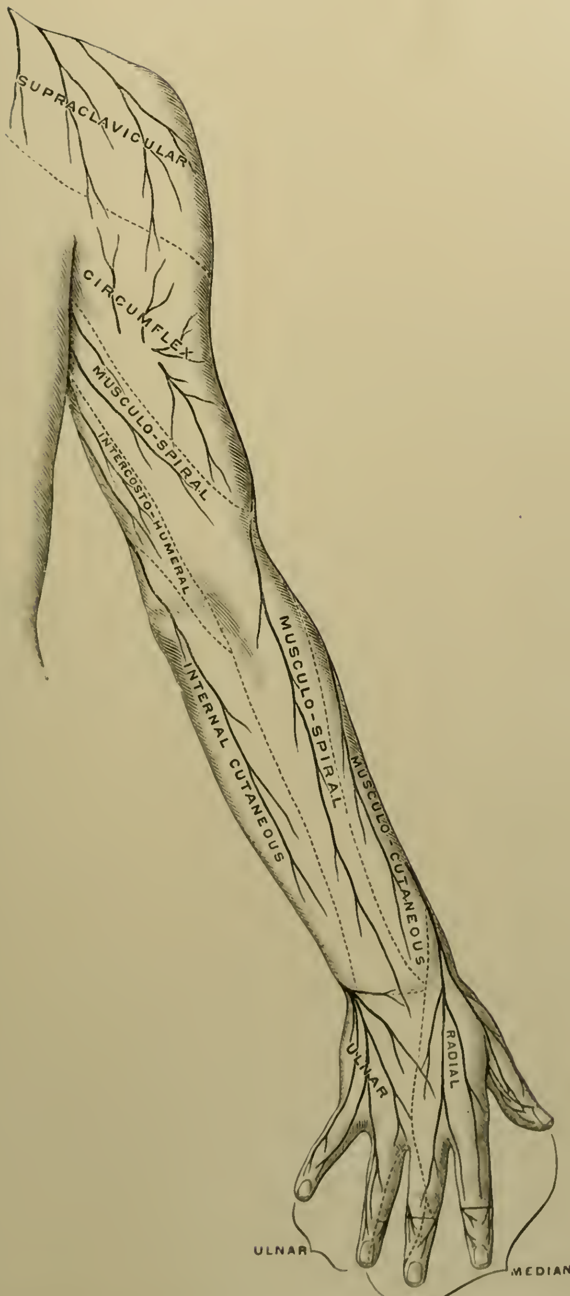
Motor Nerve Supply.—*The ulnar nerve* supplies the interossei, adductor pollicis, inner head of the flexor brevis pollicis, and the two inner lumbricales, as well as the muscles of the hypothenar eminence and the inner half of the flexor profundus. Hence **paralysis of the ulnar** is *followed by* inability to adduct the thumb (adductor), to flex the last phalanx (profundus) of the two inner fingers, or to flex the first (interossei) or extend the last two phalanges (interossei) of all the fingers. Hence the hand is held with the first phalanges extended and the other phalanges (except the terminal phalanges of the two inner fingers) flexed, giving the position known as "claw hand." Abduction and adduction of the fingers is interfered with, owing to paralysis of the interossei. The muscles of the hypothenar and ulnar part of the thenar eminences are paralyzed and become atrophied.

As **the median nerve** supplies the rest of the long flexors and those thumb muscles not supplied by the ulnar, and also the two outer lumbricales, **its paralysis** is *followed by* inability to flex the second phalanx of all fingers, the last phalanx of the middle and index fingers, to flex or abduct the thumb, to pronate the hand, and to flex the wrist, except by means of the flexor carpi ulnaris. The thumb is held adducted and extended. After the last phalanges of the two inner fingers is flexed, continued action of their flexor profundus tendons will flex the second phalanges. Flexion of the first phalanges with extension of the last two can be performed in all fingers by means of the interossei. Except as the result of wounds of the axilla or wrist isolated paralysis of the median nerve is rare.

On the dorsum of the hand **the extensor tendons** are united together by connecting slips (Fig. 77), so that it is difficult to extend one without the neighboring finger. The index finger can be extended alone most readily, next the little finger, for they are joined by only one band to the tendon of the neighboring finger. The ring finger is extended alone with the most difficulty. The extensor tendons serve the place of posterior ligaments for the three joints of the fingers. When the last two phalanges alone are flexed, the first is steadied by the extensor tendons, so that in paralysis of the latter this movement is not possible. When a finger is torn out it takes with it one or more tendons, most often the flexor profundus tendon if only one is avulsed.

Felon or whitlow is an inflammation usually commencing on the palmar aspect of the terminal phalanx, in the soft parts, tendon sheaths, or periosteum. However it begins, unless it is promptly incised, it is *liable to extend* to the synovial sheath of the tendon or to the periosteum. The latter is readily attacked as it is not covered by the tendon sheath beyond

FIG. 84



Cutaneous nerve supply of the upper limb, dorsal aspect. (W. Keiller.)

the base of the terminal phalanx. As the result of the involvement of the periosteum, the bone often necroses, but usually only the terminal part, for the base, which is an epiphysis not uniting with the shaft until about the eighteenth year, is protected by the insertion of the flexor profundus tendon, probably by keeping up its blood supply. Owing to the absence of the tendon sheath over the distal phalanx, except at its base, the infection is not so likely to extend to the sheath unless it involves the middle or proximal phalanges. When the synovial sac is involved the inflammation extends to the end of the sac, opposite the head of the metacarpal bone, except in case of the thumb or little finger, in which it may extend into the palm, beneath the annular ligament and up into the wrist, etc. (see p. 218–19).

Bones and Joints.—In **fracture** of the **metacarpal bones** but little displacement is allowed, as they are splinted to the neighboring bones by the interosseous muscles and the transverse ligaments. The **carpometacarpal joints** of the first three fingers allow of but little motion, that of the little finger and especially that of the thumb allow more free motion. The preservation of these joints is of great importance to the usefulness of the hand. Under all circumstances as much of the thumb as possible and a portion of the fingers or hand, to oppose it, should be saved, to preserve the forceps or grasping function of the hand.

Dislocations of the metacarpophalangeal and interphalangeal joints are *common.* **Dislocation of the first phalanx of the thumb backward** is the *most common and the most important* on account of its common occurrence and the frequent *difficulty in its reduction.* The condylar head of the metacarpal bone is most prominent on its outer side. The tendon of the long flexor muscle lies nearer the inner than the outer side. Its containing sheath extends up to and is connected with the glenoid ligament. The short muscles of the thumb are relaxed by pressing the metacarpal bone into the palm (adduction). The extensors and long flexors are relaxed by slight abduction of the wrist. As the attitude of dislocation (hyperextension) is maintained by the tension of the short muscles attached to the thumb, these two movements, relaxing as much as possible the muscles attached to the thumb, favor the reduction of a dislocation. The difficulty in reduction has been *explained* in many ways: the buttonholing of the head of the metacarpal bone between the two sets of muscles which centre in the sesamoid bones, the entanglement of the long flexor tendon around the inner side of the neck of the metacarpal bone, the intervention of the anterior glenoid ligament between the two joint surfaces, etc. The latter explanation is thought by Faraboeuf to cover most cases. The *glenoid ligament* is torn from the metacarpal bone, to which it is loosely attached, but remains fixed to the phalanx and is carried back with it. If now the thumb is straightened, as it may be, and traction is made in this position, the muscles attached to the sesamoid bones, which are attached to the ligament, pull the latter back, and if the phalanx is brought into place by this traction, the glenoid ligament lies between the joint surfaces with its anterior face applied to the head of the metacarpal bone. In any case traction in the straightened position

should never be employed in reduction for fear of changing a simple into a "*complex dislocation*," but rather traction in the hyperextended position followed by flexion. According to Stimson, the resistance to reduction is due to the torn edges of the anterior ligament drawn closely about the metacarpal bone behind its head. This condition is frequently found on arthrotomy, performed to reduce the dislocation, and a slight nicking of the tense edge makes reduction easy.

As it is important to know *from which spinal nerves and segments* the various *nerves of the arm spring* and the muscles supplied by them are innervated, for the purpose of diagnosis of nerve injuries of the upper limb, the following table is added:

Nerves.—Suprascapular and circumflex nerves, 5, 6, C.; posterior thoracic (nerve of Bell) and musculocutaneous, 5, 6, 7, C.; internal cutaneous and ulnar, 8, C., and 1, D.; lesser internal cutaneous (nerve of Wrisberg), 1, D.; musculospiral, 5, 6, 7, 8, C.; median, 6, 7, 8, C., and 1, D.; nerve to rhomboids, 5, C.; nerves to subscapularis and teres major (upper and lower subscapular), 5, 6, C.; nerve to latissimus dorsi (middle or long subscapular), 6, 7, 8, C.

The entire *brachial plexus* may be ruptured or torn away from its attachments to the cord, or one or more of its cords, primary divisions or branches may be torn, stretched, or compressed. The common cause of rupture of one or more cords of the brachial plexus is the violent abduction of the head from the shoulder, and a common example of this is seen in brachial birth palsy, in which this abduction occurs during delivery. The upper cords or roots are first and most often involved in brachial palsy. The **cutaneous distribution** of the nerves of the arm is shown in Figs. 83, 84.

CHAPTER III.

THE THORAX.

THE THORACIC WALLS.

Shape and Size.—The *adult thorax,* covered by the soft parts, appears *conical,* with its base above and its apex below, and flattened from before backward. Its *circumference* at the apex of the axilla is considerably greater *in the male* than that at the level of the nipple or at the base of the xiphoid process. *In the female* the circumference at the nipple is nearly as great as that at the axilla and the latter is considerably less than the similar measurement in the male. *In the phthisical* the upper circumference is less than the lower (Hirtz). The *senile thorax* is narrowed above and lengthened so as to be conical with the base below. This is due to a sinking of the front of the ribs, due to the relaxed tone of the muscles. *In the fetus* it is flattened laterally, the anteroposterior diameter being the greater. *In the infant* at birth the thorax is short, nearly circular on cross-section, and conical, with its base below. These differences in the infant are due, respectively, to the more horizontal position of the ribs, the absence of the angles of the ribs, and the greater size of the liver, as compared with the lungs.

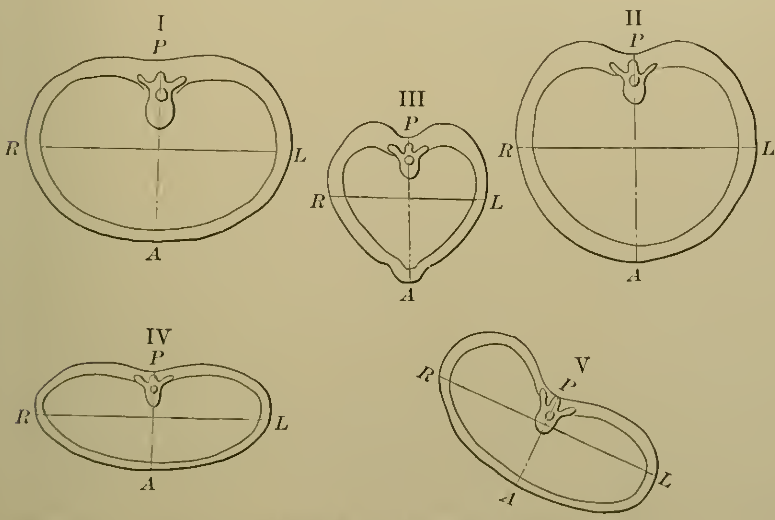
The *length* of the posterior wall is over twice that of the anterior wall in the median line (31.5 cm. to 15.5 cm.) and the length of the side of the thorax is greater than that of the posterior wall. The *height* of the thorax increases with that of the body, but not proportionally, the *transverse diameter* increases less and the *anteroposterior diameter* still less. The greater height of the body is largely due to the length of the lower extremities. However, a too small circumference of the thorax in a tall subject is thought to indicate a predisposition to phthisis. In the Prussian army those whose chest circumference is less than half the body height are regarded as narrow-chested and predisposed to tuberculosis, unless the chest is widened by drill. The *thorax of the female* is relatively smaller than that of the male, is less flattened, and more rounded. The *two halves* of the thorax are usually *unsymmetrical,* the right measuring more (1 to $1\frac{1}{2}$ cm.), owing to the greater use of the right side.

When the soft parts covering it have been removed, the thorax is seen to be conical in shape with the apex above. Hence the lung capacity is not indicated by the breadth of the shoulders, but rather by the size of the base of the neck.

Abnormal and Pathological Forms of the Thorax.—*Occupation* may affect the shape, as by the pressure of tools depressing the ster-

num and flattening the thorax. *Corsets* may so press in the lower ribs as to make the thorax spindle-shaped, or even smaller below than above. In **pigeon breast** the sternum and costal cartilages are protruded in relation to the ribs, like the sternum of a bird, and the sides of the chest are flattened. It occurs especially in rickety children, in whom the long bones are not properly ossified, particularly at their epiphyseal junctions, as at the costochondral. In such a case there is often obstruction in the respiratory passages, due to adenoids or hypertrophied tonsils, so that in inspiration the air cannot enter the chest fast enough to make the air pressure within equal to the atmospheric pressure without the thorax. Hence the weakest part, or that along the costochondral line, is pressed

FIG. 85



Outlines of I, normal chest; II, emphysematous chest; III, pigeon breasted chest; IV, flat or tuberculous chest; V, scoliotic oblique chest. Diagrammatic.

inward, becoming a deep groove and making the sternum relatively prominent. In rickets the enlargements of the ends of the ribs along this line is often palpable and sometimes visible, receiving the name of *beaded ribs*, or, if numerous and bilateral, "*rickety rosary*."

Two opposite pathological types of thorax may be distinguished. **The emphysematous type** *or the type of permanent inspiration* is like that seen in pulmonary emphysema. The chest is barrel-shaped, enlarged in circumference but shortened vertically. As it is in the position of inspiration at all times, the capacity of the chest cannot be much increased. The upper part is chiefly affected. An approach to this type is normal as adult life advances. The **type of permanent expiration** or the *phthisical type* (habitus paralyticus) is the opposite of the above. The chest appears flattened and lengthened. It may predispose to phthisis or be the result of it. The upper part of the thorax is especially contracted.

Again, in posterior and lateral curvatures of the thoracic spine the thorax is deformed. In **posterior curvature of the spine** (usually the result of Pott's disease) the sternum is thrust forward and the ribs are more oblique, approaching the pelvis so that the free ribs overlap the iliac crests. In **lateral curvature** the ribs on the convex side of the curve are more separated from one another than normal, those on the concave side more pressed together and sometimes so depressed as to touch or even overlap the iliac crests. Owing to the rotation of the vertebræ the ribs on the convex side bulge posteriorly on account of the prominence of their angles, and the scapula is carried back with them, making a "hump" on that side. On the concave side, usually the left, the front of the chest is abnormally prominent. As a result of pleuritic or pericardial effusions, aneurysm, tumors, etc., the *thorax* may become *protruded* and it may become *sunken in* from retraction of an adherent lung, etc. Such protrusions and retractions may involve a part or the whole of one or both halves of the thorax.

The Internal Configuration.—The internal configuration of the thorax is somewhat *heart-shaped,* owing to the forward projection of the vertebral bodies, which renders the internal sagittal diameter but 1 cm. more than one-half the same measurement externally. Owing to the backward projection of the angles of the ribs and the fact that the line of gravity descends in the cord of the backward curve of the thoracic vertebræ there is nearly as much space within the thorax behind the line of gravity as there is in front of it. Hence the erect position is easily maintained without the excessive muscular action which is necessary in animals, in which these conditions do not prevail. Furthermore, in the human subject, the backward projection of the angles of the ribs on either side to about the level of the vertebral spines renders possible the supine position, which is not possible in animals, as in them the spines project mesially without the corresponding lateral projection of the ribs.

Boundaries of the Thorax.—The thorax is bounded *in front* by the sternum, costal cartilages and the spaces between them, *laterally* by the ribs and intercostal spaces, *behind* by the thoracic vertebræ and the posterior ends of the ribs and intercostal spaces. The **bony thorax** *covers* several of the abdominal viscera in addition to the thoracic, hence, besides the thoracic cavity proper, it bounds part of the abdominal cavity, the two being separated by the obliquely placed diaphragm (see p. 239). The latter, therefore, forms the convex floor of the thoracic cavity proper. The *apices of the lungs* and the domes of the pleural cavities extend through the small **superior aperture** of the thorax, as well as the trachea and esophagus and the vessels, nerves, and muscles which pass between the neck and the thoracic cavity. This superior aperture *connects* the neck and the thoracic cavity. It is *formed by* the first ribs, first thoracic vertebra, and the top of the sternum, is kidney-shaped, and slanted slightly downward from behind forward. It *measures* 5.5 cm. ($2\frac{1}{4}$ in.) from behind forward and 10.5 cm. ($4\frac{1}{4}$ in.) transversely.

To assist in the topography of the chest we distinguish certain *vertical lines* in addition to the median or midsternal line, *i. e.,* the *sternal*

line along the side of the sternum, the *mammary line* through the nipple, the midclavicular line through the middle of the clavicle, practically identical with the mammary line, the *axillary line* midway between the the anterior and posterior axillary lines, which are drawn through the lower ends of the anterior and posterior axillary folds, and the *scapular line* drawn through the inferior angle of the scapula. The parasternal line is midway between the sternal and mammary lines and the costo-clavicular line connects the sternoclavicular joint with the tip of the eleventh rib on the same side.

Landmarks of the Thoracic Walls.—In the *median line* anteriorly the top of the sternum corresponds to the cartilage between the second and third thoracic vertebræ; the junction of the manubrium and body of the sternum is indicated by a readily palpable, prominent, transverse ridge (angulus Ludovici), which is continuous with the second costal cartilages. This is the easiest and most reliable point to start from in counting the ribs. It corresponds to the disk between the fourth and fifth thoracic vertebræ. The junction of the body and ensiform process of the sternum is readily palpable as a ridge, for the ensiform is at a deeper level than the sternal body. This junction corresponds to the articulation of the seventh costal cartilage with the sternum, and to the lower part of the ninth thoracic vertebra behind. It is also on a level with the lowest point of the fifth rib.

Laterally the nipple lies on a level with the anterior end of the fourth rib (Hyrtl), or in the fourth space, nearly 2.5 cm. (1 in.) external to the costal cartilage and vertically in line with the middle of the clavicle. The virgin breast covers the ribs from the third to the sixth. The lowest point of the seventh rib (the junction of the rib and costal cartilage) lies in the mammary line. The costochondral junction of the ribs above the seventh lie internal to this line, that of the lower ribs external to this line, in an oblique line extending downward and outward. The lower border of the pectoralis major corresponds to the fifth rib, the first visible serration of the serratus magnus to the fifth rib, the largest serration to the sixth rib. *Posteriorly* the scapula covers the ribs from the second to the seventh (sometimes the eighth). Hence the first interspace below the scapula is the seventh (sometimes the eighth). Owing to the obliquity of the ribs we find in a sagittal section in the mammary line that the first rib in front corresponds to the fourth rib behind, the second to the sixth, the third to the seventh, etc., each rib below the first in front corresponding to the fourth one lower in the series behind.

The Layers of the Thoracic Wall.—**The Skin over the Sternum.**—The skin over the sternum is a favorite locality for *keloid growths*. Gummata also are often found in the soft parts covering the sternum, especially the periosteum. The **subcutaneous tissue** of the thoracic wall may be the seat of extensive *emphysema* in some fractures of the ribs or in perforating wounds of the thorax.

The Sternum.—The sternum is very variable in *length* and is often not in proportion to the height of the body. I have seen the sternum 26 cm. ($10\frac{1}{2}$ in.) long in a man of average height. In women the sternum, and

especially its body, is relatively shorter than in men. The holes or clefts in the lower part of the sternum, due to defects in its development from two lateral halves, may afford pus an entrance to or an exit from the mediastinum. After a median division of the sternum the two halves may be retracted so as to expose for ligation the great vessels in the mediastinum. It may be trephined to open mediastinal abscess or for pericardial paracentesis.

The sternum may be *fractured* by *direct violence,* as by the violent contact with the chin, or by *indirect violence,* as by the traction of the muscles when the body is forcibly bent backward. It is often associated with fracture or dislocation of the spine due to hyperflexion or extension. The fracture is usually transverse and occurs most often at or near the juncture of the manubrium and body, the narrowest part of the bone. The body of the sternum with the ribs is commonly *displaced* forward. The lesion is often a *dislocation* in whole or in part through the joint between the manubrium and body. In old age when this joint is ossified the tendency to fracture is increased by making the chest more rigid. Fracture of the sternum is *not common* owing to the elasticity of the ribs and costal cartilages which support it, the elasticity of the sternum which is formed of two parts articulated together at a slight angle, and the soft cancellous character of the bone. The cancellous structure and its exposure to slight injuries accounts for its being often attacked by tuberculous or syphilitic caries and for its ready absorption from the pressure of an aneurysm.

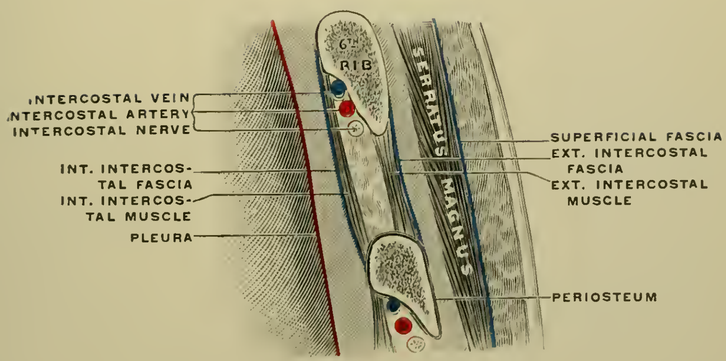
The tip of the **ensiform cartilage** may bend forward or backward. The ensiform often presents median apertures, and it, as well as its articulation with the sternum, may become ossified in advanced age. The **costal cartilages** by their *elasticity* increase the resistance of the sternum and ribs to injury. When they become *ossified* in advanced age the ribs and sternum are more exposed to fracture. They increase in *obliquity* from the third down, and in *length* down to the seventh. When the ribs are raised in inspiration, the costal cartilages are raised and become more horizontal. This throws the ribs outward, increasing the transverse diameter of the thorax. When inspiration is completed their *resiliency* brings them, and with them the ribs, into their normal position so that quiet expiration requires no muscular action. At the border of the sternum only the first two or three interspaces between the costal cartilages are wide enough to operate through, as in ligation of the internal mammary artery. Below this the spaces are so narrow that resection of the cartilages is necessary to expose the parts beneath.

The Ribs.—The ribs increase in *obliquity* from above downward. They increase in *length* as far as the seventh, and thence they decrease. The *raising* of the ribs in inspiration shortens the thorax but increases the anteroposterior and the transverse diameters. The latter diameter is also increased by the throwing out of the ribs at the side, in the *rotation* that occurs on an axis passing through their two articulations. This rotation accounts for all the movements of the ribs.

The ribs are unequally exposed to injury. The upper ribs, first and

PLATE XXIII

FIG. 86



Vertical Section of the Sixth Intercostal Space at the Junction of its Posterior and Middle Thirds. (Tillaux.)

second, are protected by the overlying pectoral muscle and the clavicle the lower or false ribs by their small size or their mobility, due to their long cartilages, etc. Hence it is the ribs in the middle of the series, fourth to eighth, that are most often *fractured*. In advanced age the ribs are more liable to fracture, owing to the ossification of the cartilages.

Fracture may be due to direct or indirect violence, most often to the former. It may also be due to muscular violence as in coughing, parturition, etc.; but in such cases the ribs are probably pathologically weakened. **Indirect fractures** are due to some excessive pressure, such as being run over. This tends to increase or decrease the curve of the ribs, by pressing their extremities together or apart, until they break, theoretically near the middle of their curve, but practically in their anterior third near the point of application of the violence or in the posterior third. Such violence usually fractures more than one rib, and is liable to injure the viscera as well. Theoretically, the ends should project outward toward the skin, but practically, we find that, owing to the thick periosteum and the intercostal muscles which bind the ribs firmly together, *displacement* of the ends does not occur to any great extent, especially if only one rib is fractured. Hence there is rarely any *deformity* unless several consecutive ribs are fractured. For the same reason, and the intraperiosteal character of many fractures, crepitus and false motion are often not to be elicited. It is probably true, however, that injury of the lung by the fragments, though it may occur in indirect fractures, is less common than in **direct fractures**, in which the lesion is beneath the blow and the fragments, if *displaced* at all, tend to be driven inward, lacerating the pleura and lung, and causing hemo- or pneumothorax, subcutaneous emphysema, hemoptysis, pleurisy, etc. In both forms of fracture the side of the chest injured is strapped to lessen the movements of the ribs and thereby the pain on that side. The tendency to involuntary immobilization of the chest wall in inflammatory affections or after injury is of some diagnostic value.

Notwithstanding the constant movement at the articulations of the ribs, they are singularly free from disease, and dislocation is very rare.

Resection of one or more ribs is practised for necrosis or caries, often tuberculous, syphilitic, or post-typhoidal, for drainage of an empyema, or in the Estlander or Schede operation for chronic empyema. In resection the periosteum is incised and separated from the rib, *i. e.*, the rib is resected *subperiosteally*. In this way we avoid injury to the pleura, which is separated from the ribs by the periosteum and the *endothoracic fascia* lining the chest cavity. The *intercostal vessels and nerves*, in the grooves behind the lower border of the rib, are also avoided, for they lie behind the periosteum (Fig. 86). Resection of an inch or so of rib is done to allow more free drainage than is secured through the narrow intercostal spaces. The seventh rib, or the rib above or below it, in the midaxillary line is usually selected. In the scapular line we may resect a rib or two lower. As the ribs form a firm arch, there is no opportunity for retraction of the thoracic wall to obliterate the cavity of a chronic empyema, and the lungs are bound down and cannot expand. The Estlander and Schede operations meet this difficulty by resecting several inches of a

number of consecutive ribs over the cavity. The arch of the ribs is thus broken, and both ends, as well as the intervening soft parts, may sink in and help to close the cavity beneath.

The Intercostal Spaces.—The intercostal spaces are narrower behind than in front, in expiration than in inspiration, and, in lateral inclination of the thorax, on the side toward which it is inclined than on the opposite side. The third space is the widest, and next in order the second, first, fourth, etc. Any of the first five spaces will admit the index finger. The *contents* of the intercostal spaces include the external and internal intercostal muscles, covered externally by a thin fascial layer and internally by the endothoracic fascia and separated from one another by a layer of cellular tissue in which lie the intercostal vessels and nerves (Fig. 86). Between the endothoracic fascia and the pleura is a loose subpleural cellular layer. Pus from disease of the thoracic vertebræ or the posterior part of the ribs may work around in the intercostal spaces and appear even as far forward as the sternum.

Vessels of the Thoracic Wall.—**The Intercostal Arteries.**—The aortic and superior intercostals supply intercostal arteries for each space. Between the vertebræ and the angles of the ribs the intercostal vessels pass more horizontally than the ribs till they reach the cover of the lower border of the ribs, near the angles. In crossing this part of the intercostal spaces they give off smaller branches which pass to and along the upper margins of the ribs, and they are exposed to injury by incisions or paracentesis. Similarly in the anterior third of the intercostal spaces, where they anastomose with branches from the internal mammary artery, they abandon the protection of the ribs and are more or less exposed. But here, owing to their small size, their injury is not as serious as posteriorly, where a fatal hemorrhage may result. Hence *incision and paracentesis* are to be avoided posteriorly and anteriorly and practised more at the sides. As the vessels lie much nearer the pleura than the surface, they are likely to bleed into the pleural cavity when wounded unless the wound is very freely open superficially. It is remarkable that the intercostal vessels, lying in such close contact with the ribs, are almost never injured in fractures of the ribs. This is explained by the protection afforded by the periosteum and the fact that the fragments are rarely displaced. Owing to the protection of the ribs, in the greater part of their course the intercostal arteries are seldom wounded, but if wounded they are difficult to secure without injury to the pleura.

Paracentesis may be done with care in any space within the limits of the pleura where fluid can be diagnosticated. It is usually performed in the sixth or seventh spaces midway between the axillary lines, where the overlying muscles are thin, or near the posterior axillary line, or in the seventh or eighth spaces just outside the angle of the scapula, where the latissimus dorsi must be punctured. Especial care must be taken in the lower spaces, like the ninth in the posterior axillary line, not to puncture the diaphragm, but when there is much fluid the diaphragm is much pressed down. The needle or trocar is entered midway between the ribs, to avoid the intercostal vessels, and in inspiration, for the spaces

are then wider. The spaces may be widened laterally by bending to the opposite side. The same rules apply to *incisions*, which, however, can be made in the lowest spaces with greater safety than puncture, as they are not made blindly.

The Intercostal Veins.—The intercostal veins accompany the arteries, lying above them. Those in the upper six or seven spaces anastomose with the branches of the axillary vein (Braune). The subcutaneous veins of the thorax form an anastomosis between the axillary and the femoral veins, usually through the superficial epigastric veins (see the Veins of Abdominal Wall).

The Internal Mammary Artery.—The internal mammary artery runs a finger's breadth from the sternal margin behind the cartilages and interspaces. It is *separated from the pleura* in the upper two spaces by the endothoracic fascia, which is here thicker than elsewhere, and in the succeeding four spaces by the triangularis sterni muscle. As it is a vessel of some size, serious or fatal hemorrhage may follow its injury, and the bleeding is most likely to occur internally into the pleural cavity. As wounds of this artery are uncommon, its **ligation** is seldom called for but may be done in one of the three or four upper spaces. Below this the spaces are so narrow as to require resection of the cartilages. The third space is preferable, as this is wider in front than the fourth and the pleura is protected by the intervention of the triangularis sterni and not merely by the endothoracic fascia, as in the second. On either side of the artery, especially mesially, we may find sternal lymph nodes.

The Intercostal Nerves.—The intercostal nerves (or anterior divisions of the thoracic nerves) *lie* below the arteries in their course behind the lower border of the ribs, though they are at first above them in the upper four spaces. They *supply* the costal pleura as well as the skin over the greater part of the abdominothoracic region, so that pain over the upper part of the abdomen may be peripheral pain due to pleurisy or to pressure on the nerves by pleural collections of fluid, thoracic tumors, caries of the lower thoracic vertebræ, etc. The *lateral cutaneous branches* perforate the thoracic wall at the digitations of the serratus magnus and the external abdominal oblique. In intercostal neuralgia "tender points" are found where these lateral branches, the anterior cutaneous and less often the cutaneous branches of the posterior primary division, pierce the muscles, *i. e.*, midway between the mammary and axillary lines, near the parasternal line, and near the median line posteriorly, respectively. The lateral cutaneous branch of the second nerve crosses the axilla (Fig. 67) to end in the skin of the inner and back part of the arm (*intercostohumeral nerve*), where pain may be felt in pleurisy of the upper part of the pleura, in angina pectoris, or from pressure on the nerve in axillary suppuration or in enlargement of the axillary lymph nodes. The intercostal nerves supply both the intercostal and the abdominal muscles (see also Nerves of Abdominal Muscles). It should be remembered that the skin over the upper part of the thorax is also supplied by the superficial descending branches of the cervical plexus. The posterior divisions of the thoracic nerves descend a considerable distance before ending in the skin.

This partly accounts for the fact that the *line of anesthesia* in fracture of the thoracic spine and the line of pain and cutaneous eruption in herpes zoster is nearly horizontal and not oblique. This also depends upon the fact that the lesion involves the spinal segments rather than the peripheral nerves.

The **superficial lymphatics** mostly enter the axillary nodes; others, near the sternum, may enter the sternal nodes along the internal mammary artery or cross the median line to the opposite axilla; while others above may cross the clavicle and enter the subclavian nodes. The deeper lymphatics in the intercostal spaces run in two sets, the deeper ones, just beneath the pleura and receiving its lymph channels, pass forward to the sternal nodes along the internal mammary artery; the more superficial ones pass backward, through small nodes at the back of the intercostal spaces, and enter the thoracic duct. These deeper vessels anastomose with those entering the axillary nodes.

THE BREAST.

The breast (*mamma*) at birth and up to puberty is equally undeveloped in both sexes. A slight secretion of a collostrum-like fluid, with evidences of inflammation, may sometimes occur in the newborn and in boys at the time of puberty. Very rarely the breast is well-developed and functionally active in men.

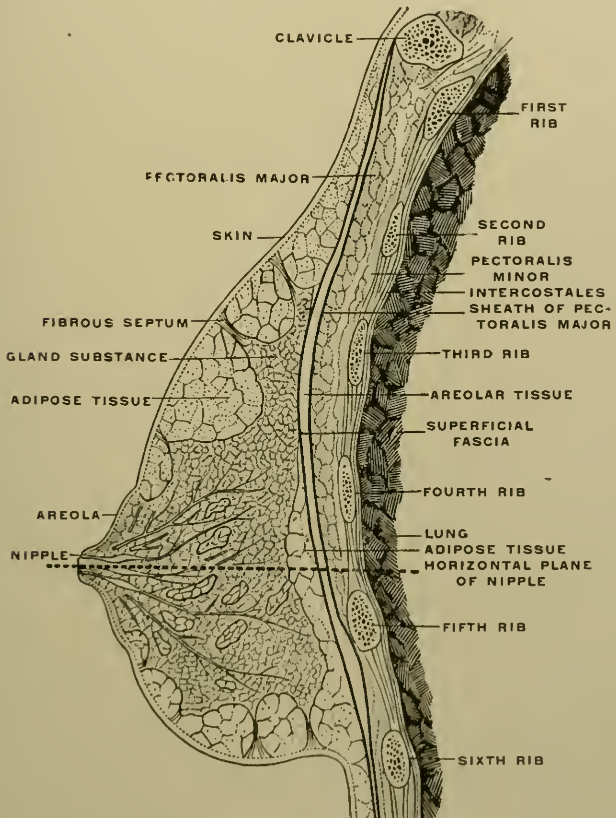
The *female breast,* though it develops much at puberty, does not reach its *full functional development* until the end of pregnancy and during lactation. After lactation the breast returns to its former condition until again stimulated by a subsequent pregnancy. After the menopause the breast atrophies, and at this time is quite likely to be attacked by cancer.

The *virgin breast* is hemispherical, *extending* between the third and sixth ribs and between the sternal and anterior axillary borders. Its *circumference* is not quite circular, but presents three cusps, one toward the sternum and two toward the axillary line, one above and one below. After repeated pregnancies the breast becomes more flabby and pendent, so that its position is not a reliable landmark. In certain *black races,* as in the Basutos, it is flask-shaped and may even be flung over the shoulder or beneath the axilla, so that the infant may suckle on the back.

The breast (Fig. 87) *lies upon* the pectoralis major muscle, about one-third of the gland overlapping it onto the serratus magnus, and, if large, onto the origins of the external oblique and rectus. The *superficial fascia* of the region splits to enclose and support it, and sends fibrous processes to connect the several lobes together. Fibrous *trabeculæ* connect the gland with the overlying skin and more loosely with the underlying pectoral fascia. The enclosing fascia is rich in *fat,* which thus comes to lie in front and behind the gland and between its lobes. Except during lactation, and oftentimes then, the *size* of the mamma is largely due to the relative amount of this fat, which gives the breast, with its 15 to 20 lobes, its smooth and uniform contour and elastic consistency. Hence the large size of the

breast is no indication of good nursing qualities but often the reverse, the fat being developed at the expense of the gland tissue. During lactation and in conditions of emaciation the fat is largely absorbed, so that the gland feels more distinctly lobular. *Posteriorly* the mamma is loosely connected with the pectoral fascia by loose connective tissue which may enclose large lymph spaces, the so-called submammary bursa. This is one of the sites selected for injection of hot normal saline solution in shock or sepsis.

Fig. 87



Right breast in sagittal section, inner surface of outer segment. (Gerrish, after Testut.)

Normally the breast should be *movable* in all directions on the pectoral muscle; the failure of such mobility indicates deep extension of the growth in cancer of the breast. This mobility should be tested after the muscle is made firm by its contraction, and especially in the line of its fibers. At the same time the breast moves somewhat with the movement of the muscle, hence the arm should be held at rest in inflammation of the gland.

It is most important to remember that small glandular extensions may pass from the base of the gland to and even through the pectoral

fascia so as to lie upon or in the muscle. It follows that every operation of excision of the breast for cancer, to be thorough, should remove this fascia and the surface, if not the entire thickness, of the underlying pectoral muscle. Similarly the fibrous *trabeculæ* (*suspensory ligaments of Cooper*), which connect the gland with the skin, may contain true glandular tissue (Stiles), and explain the frequent extension to the skin; hence no overlying skin should be left in excision for cancer. The contraction of a carcinoma pulling on these trabeculæ may produce a number of small depressions or dimples, like those on an orange, which is a very valuable diagnostic sign of cancer.

The *overlying skin*, except that of the areola, should be freely movable, but in abscess or advanced carcinoma it may become adherent, and in some cases of the latter it is infiltrated with small nodules of carcinoma. In lactation or in cases of carcinoma or sarcoma the large and numerous *subcutaneous veins* are often very plainly visible. The *skin of the areola and nipple* is fatless, pigmented, very thin and sensitive, and adherent to the parts beneath. Besides highly developed papillæ, the skin of the nipple contains numerous *sebaceous glands*, whose secretion protects the nipple from the saliva of the infant and guards it from **fissures**. The latter occur most often in the groove between the nipple and the areola, where none of these glands open.

Beneath the skin of the nipple and areola are *pale muscle fibers*, both circular and radiating, which act as a *sphincter* on the lacteal ducts traversing the nipple. By their contraction a part of the areola is drawn up into the nipple, thus lengthening and erecting the latter, which is not really an erectile body. The *lacteal ducts*, one for each lobe of the gland, after enlarging into a spindle-shaped ampulla or reservoir beneath the areola, converge to and traverse the nipple to open separately by fine orifices ($\frac{1}{2}$ mm. in diameter) near its tip.

Besides ordinary **eczema** of the areola and nipple, these may be the seat of a chronic, superficial, finely granular, raw condition known as *Paget's disease* of the nipple, which usually results in epithelioma of the lacteal ducts. By a contraction of the lacteal ducts, or of new connective tissue about them, in scirrhus cancer, centrally situated, the *nipple* may be *retracted* so as to present a depression instead of a projection.

The Nipple.—The nipple averages 12 mm. ($\frac{1}{2}$ in.) in *length, lies* a little below and internal to the centre of the gland, and points outward. In the virgin it *corresponds to* the fourth interspace (or fifth rib) 10 cm. (4 in.) from the median line, but its position is very variable after pregnancy or in old age. In some cases it is depressed below the surface so as to prevent nursing. The **consistency** of the breast is *firm* without being hard. It is not entirely uniform in all parts, but if any part is distinctly hard it is pathological. To detect neoplasms, cysts, etc., the breast should be palpated against the chest wall and compared with the opposite breast. The normal breast, if palpated between the fingers and thumb, may be mistaken for a tumor.

Abscess of the Breast.—Abscess of the breast is not uncommon during lactation, and is usually *due* to an infection carried by the lymphatics

from a fissure or eczema of the nipple or areola. It may occur in *three situations:* (1) in the fatty connective tissue superficial to the breast; (2) in the breast tissue itself or its interlobular tissue; and (3) in the loose submammary connective tissue. It occurs most often in the breast tissue, and one or more lobes or the entire organ may be involved. **Incisions** to open mammary abscess should *radiate from the nipple* to avoid damage to the lacteal ducts.

The Blood Supply.—The blood supply of the mamma comes mainly from the *long thoracic artery* (external mammary), which follows the outer border of the pectoralis minor, and from the second, third, fourth, and fifth perforating intercostal branches of the internal mammary artery, and, in addition, from the corresponding aortic intercostals and perhaps from the acromiothoracic. The *veins* follow the same course. These arteries and veins are divided in excision of the breast.

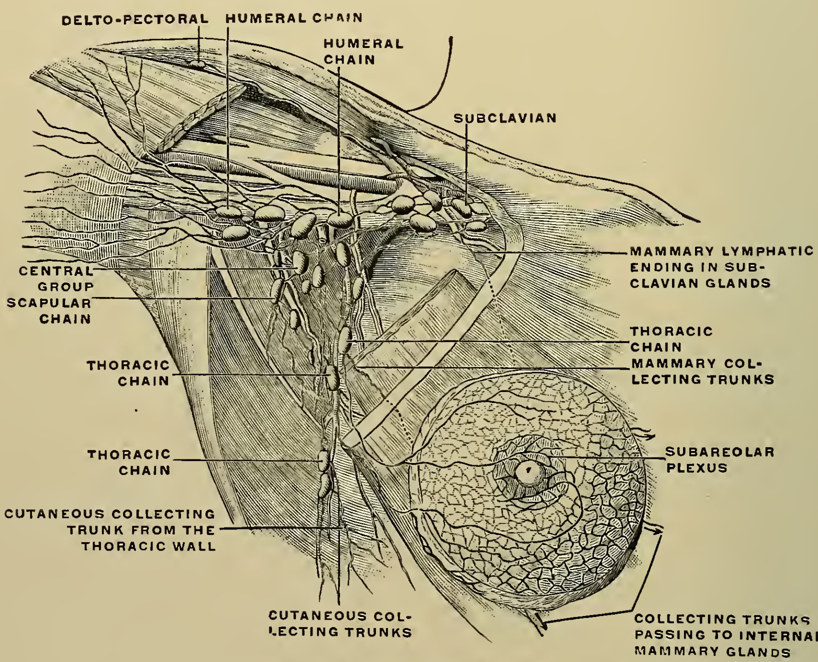
The Lymphatics.—The lymphatics are of special importance, as it is through them that metastatic infection occurs in carcinoma of the breast. The superficial or subcutaneous lymphatics at the periphery of the breast do not differ from those of adjacent regions, but beneath the areola they form a very close network from which many small trunks pass to the *subareolar plexus,* in which the majority of the deep or glandular set of lymphatics also terminate. Its principal outlet is by two or three large vessels which pass directly outward and then along and beneath the external border of the pectoralis major, perforate the axillary aponeurosis, and terminate in the pectoral group of the axillary nodes. (See Lymphatics of Axilla, p. 188.) The *first two nodes* which these vessels enter, and, consequently, the first to be affected by metastatic growth in cancer of the breast, usually lie on the third rib on the serration of the serratus magnus. From these the infection spreads to other axillary nodes and finally to the subclavicular nodes. Hence we see the necessity of *complete removal of the axillary nodes* and contents in any operation for carcinoma. In addition there are certain accessory lymph channels, of importance in metastasis. From the inner part of the gland lymph vessels perforate the pectoral muscle and pass through the intercostal spaces to the sternal nodes, along the internal mammary artery, and thus reach the mediastinal nodes, whence indirectly the liver, pleura, and lungs may become involved. Involvement of the sternal nodes is rare, probably due to the atrophy of this channel in senile mammæ, in which cancer usually occurs. In 10 per cent. of cases a lymph trunk from the posterior surface perforates the pectoralis major and, ascending between it and the pectoralis minor, reaches the subclavicular nodes. As the superficial lymphatics of the inner part of the breast may cross the median line and enter the nodes in the opposite axilla, the involvement of the latter sometimes occurs.

As the mamma is *supplied* by the *cutaneous branches of the second, third, fourth, and fifth intercostal nerves,* abscess or other painful affections of the breast may cause pain referred to the side or back of the thorax (intercostal trunks), the region over the scapula (posterior divisions of the thoracic nerves), or down the arm (intercostohumeral branch of the second intercostal). Pain shooting up the neck is probably along the

supraclavicular branch of the cervical plexus, which reaches the upper part of the gland and also communicates with the second intercostal.

Of the neoplasms of the female breast 85 per cent. are carcinomatous. They originate most frequently in the upper and outer quadrant. From what has been said above, as to the lymphatics and the extensions from cancer of the breast, it follows that in operations for carcinoma it is necessary to remove a liberal area of overlying skin, the entire contents of the axilla, so as to include all the lymphatics, and not only the surface of the pectoralis major but the entire muscle beneath the breast. Benign tumors include fibromata and adenomata. *Sarcoma* of the breast develops from the connective-tissue stroma of the gland, *carcinoma* from the epithelial elements of the ducts and glands.

Fig. 88



Axillary glands and lymphatics of the breast.

Abnormalities.—Small *supplementary glands* are not infrequently present around or near the mamma, and may be the starting point of tumors. Occasionally *additional mammæ or nipples* exist, sometimes in the axilla, but more often (90 per cent.) below the regular glands, converging toward the median line so as to follow the course of the internal mammary and deep epigastric vessels. They may even occur in the groin. As many as three pair in one case and in another five milk-secreting glands have been observed. The occurrence of these is explained by reversion or *atavism*. *Absence* and *imperfect development* of the breasts are rare and usually associated with absence or arrested

development of the sexual organs. The *nipples* on either or both breasts may be double or even triple, or again they may be wanting. Asymmetry of the breast is common, the left is usually the larger and is more often the seat of newgrowths and of hypertrophy.

THE DIAPHRAGM.

The diaphragm, *situated* at the junction of the superior third with the inferior two-thirds of the trunk, forms the *floor of the thoracic cavity* and the roof of the abdomen. It is a double or bilateral muscle, with a central tendon. Its muscular fibers, arranged peripherally, may be divided into sternal, costal, and lumbar (or vertebral) portions. Between these portions the muscle fibers may be wanting over a greater or less space, so that the serous or subserous layers on either side come together. Thus the muscle fibers are often wanting between the vertebral part, comprising the crura and the fibers from the arcuate ligaments, and the costal part (hiatus diaphragmaticus), favoring the passage of inflammation or pus from a perinephritic abscess into the pleural cavity, or the occurrence of a hernia. Similarly between the sternal portion, from the back of the xiphoid cartilage, and the costal portion on either side are *gaps* devoid of muscle, covered above by pleura on the right side and pericardium on the left. Through these gaps pass the superior epigastric arteries and some hepatic lymphatics, on their way to the mediastinal glands. Also between the two halves of the sternal (xiphoid) insertion is usually a gap through which the cellular tissue of the mediastinum is continuous with the subperitoneal connective tissue, and through this gap inflammation and pus may pass from the mediastinum to the epigastric region or vice versa.

Through some one of the above *gaps* **diaphragmatic hernia**, usually *congenital*, sometimes *acquired*, is most likely to occur. In the former variety one of the gaps, especially the xiphocostal, may be congenitally large or a portion of the diaphragm may be deficient. The *acquired form* is due to a muscular strain or external violence. It may be suddenly acquired, as by a fall or blow, in which case there is likely to be rupture of the peritoneum and hence no sac; or gradually acquired, as by straining, coughing, etc., when a sac is usually present. Almost *any of the abdominal viscera*, but especially the stomach, colon, and omentum, *form the contents* of such a hernia in the pleural cavity. The lungs, owing to their elasticity, are never herniated into the abdomen. Many of the acute acquired cases are rapidly fatal and often are not diagnosticated antemortem, but if diagnosticated *surgical intervention* offers the only hope.

The **fleshy portion** of the diaphragm, arising in an oblique line from the base of the xiphoid cartilage to the last rib, passes at first vertically upward, connected with the inner surface of the thorax by connective tissue, to the lower limit of the pleura (see p. 212). Thence lined above by pleura (diaphragmatic) it is separated from the thoracic wall by

a cleft-like space lined by pleura (*costophrenic sinus*), into which the lung does not descend in deep inspiration. From the level of the lower border of the lung the diaphragm curves upward and inward, concave inferiorly, into the trefoil central tendon. Hence in the lower part of the bony thorax a wound involves the thoracic wall, diaphragm, and peritoneal cavity; at a higher level it involves the thoracic wall, pleural cavity, diaphragm, and peritoneal cavity; still higher the lung intervenes in the pleural cavity. Unless the lower part of the pleural cavity is filled with fluid or gas the diaphragm is in close contact with the chest wall below the lower border of the lung, a fact to be remembered in incision and aspiration here.

The **level of the diaphragm** varies between expiration and inspiration. The middle portion or *central tendon*, on the central and left leaflet of which rests the heart, stretches from the base of the ensiform process nearly horizontally backward to the vertebræ. This portion *moves slightly* in respiration (about 2.5 cm. [1 in.], Sibson), though Hyrtl thought it stationary. The pericardium and heart must necessarily follow its movements, hence its motion is slight. The *dome, or highest point* of the diaphragm, reaches the *level* of the fifth chondrosternal joint on the *right side*, or less than 2.5 cm. (1 in.) below the nipple, on *the left* the breadth of a cartilage lower, the presence of the liver making the right side higher. In *early life* the diaphragm is higher than given above, and it is lower in *old age*. The *height* of the diaphragm is *altered by pathological condition* in the thoracic and abdominal cavities. Thus it is *lowered* in pleural or pericardial effusions and in emphysema, and *raised* when extensive adhesions exist in the pleural cavities with retraction of the lung, or when tumors, fluid, or tympanites are present in the abdomen. Its level may be determined by the x-rays.

As to the **three openings** in the diaphragm, *the aortic opening* in front of the twelfth thoracic vertebra lies in or slightly to the left of the median line. The inner portion of the two crura, which arch in front of the aorta to form the aortic orifice, is fibrous, so that the contraction of the diaphragm does not cause compression of the aorta. *The esophageal opening,* above and in front of the aortic opening and to the left of the latter and the median line, is oval and surrounded sphincter-like by fleshy crural fibers. It lies in front of the ninth thoracic vertebra. Very rarely the esophageal opening is found in the right crus, in the median line, or to the right of it. I have found this condition in one case of gastrotomy, preliminary to a retrograde dilatation of an esophageal stricture, and another similar case has been reported.

The *pleura* of both pleural cavities and the *pericardium* are *closely connected* with the diaphragm, the *peritoneum* more *loosely*. The under surface of the heart resting on the central tendon of the diaphragm explains the presence of the heart beat in the epigastrium, and its exaggeration in hypertrophy of the right ventricle. The liver, stomach, spleen, pancreas, kidneys, and suprarenals are in contact with the under surface of the diaphragm, the lungs and heart with the upper surface. Subphrenic abscesses occur in the subphrenic space between the under

surface of the diaphragm and the viscera in contact with it, especially the liver. This space is divided into a right and a left half by the suspensory ligament of the liver. These abscesses are often secondary to gastric ulcer.

The diaphragm is *supplied by* the **phrenic nerves,** in paralysis of which respiration is carried on almost entirely by the intercostals, and the epigastrium sinks instead of protrudes on inspiration, as the diaphragm no longer pushes the abdominal viscera downward and forward. In *action* the diaphragm increases the vertical diameter of the thorax, but as it also raises the lower six ribs it increases the other two diameters in the lower part. When fixed in the position of inspiration by the closure of the glottis, it assists the abdominal muscles in expulsive efforts, defecation, parturition, etc., by pressing down the abdominal viscera and holding them there. The abdominal viscera press the diaphragm upward in the supine position, hence many patients with dyspnea breathe better in the sitting posture.

THE PLEURA.

The pleura of each side is a large serous sac or *lymph space* whose median or mediastinal wall is invaginated at one point (the root of the lungs) by the lung, whose outer surface it covers as the visceral or pulmonary pleura. Normally there is no pleural cavity, the opposing smooth, inner surfaces of the pleura being in contact with only a slight amount of fluid between to diminish friction. Pathologically the presence of fluid (serum, pus) or air may make a cavity. It is important to know the **limits of the pleura** both for diagnosis and treatment.

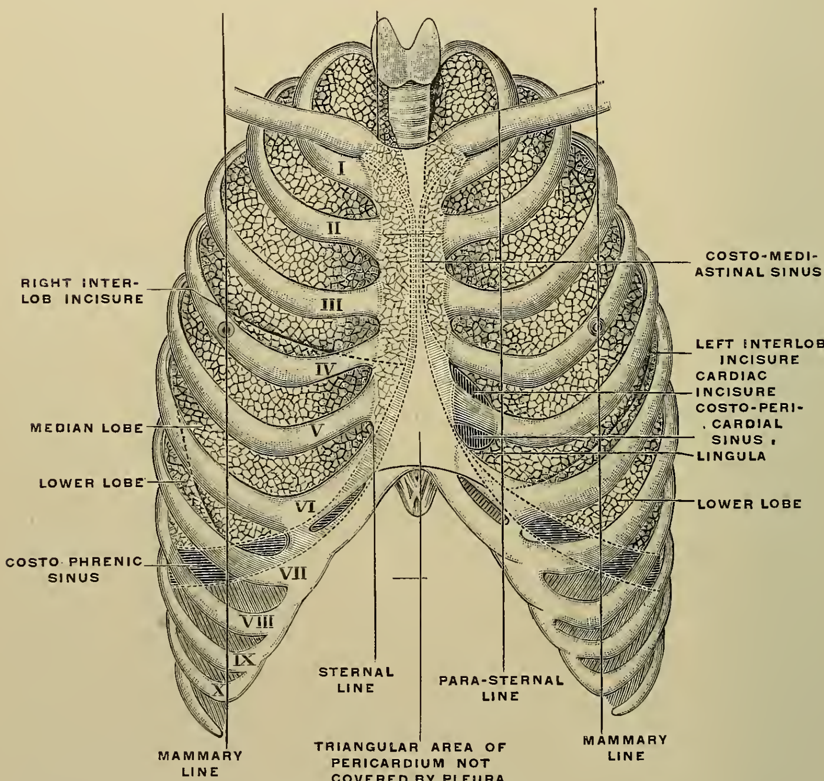
The **dome of the pleura** is completely occupied by the apex of the lung and, like the latter, is *grooved by* the subclavian artery antero-internally, hence in ligation of the artery the pleura is in danger of injury. The pleural dome and the apex of the lung *extend into* the *root of the neck* about 3 cm. ($1\frac{1}{4}$ in.), or 1 to 5 cm. above the anterior part of the first rib, but never above its neck, and 1 to 3 cm. above the clavicle in the upright position, but scarcely or not at all above it in the supine position or in forced inspiration, in which positions the clavicle is elevated. Clinically the resonance on percussion of the apex extends higher above the clavicle than its actual level. The *dome of the pleura* is *in relation* with the scaleni medius and anticus and the deep layer of the deep cervical fascia. *It lies* behind the inner end of the clavicle and the sternomastoid muscle, and projects slightly into the base of the posterior cervical triangle.

The **anterior borders,** along which the costal and diaphragmatic surfaces of the pleura meet in front, *extend* from the dome downward and inward behind the sternoclavicular joints and the sternum, *meeting* opposite the junction of the manubrium and the body of that bone a little to the left of the middle line. From this point they descend vertically, nearly, or sometimes quite, in contact, to the level of the fourth or fifth cartilage, whence they *diverge* to reach the seventh chondrosternal

16

junction, leaving between them a triangular area of sternum in contact with the pericardium. The *left pleura,* below the fourth cartilage, passes along the left border of the sternum, or at most the inner ends of the fourth to the sixth costal cartilages, but does not bend outward, as does the cardiac incisure of the lung, to leave the pericardium bare. Hence under normal conditions the pericardium cannot, as a rule, be punctured through an interspace without traversing the pleura.

Fig. 89



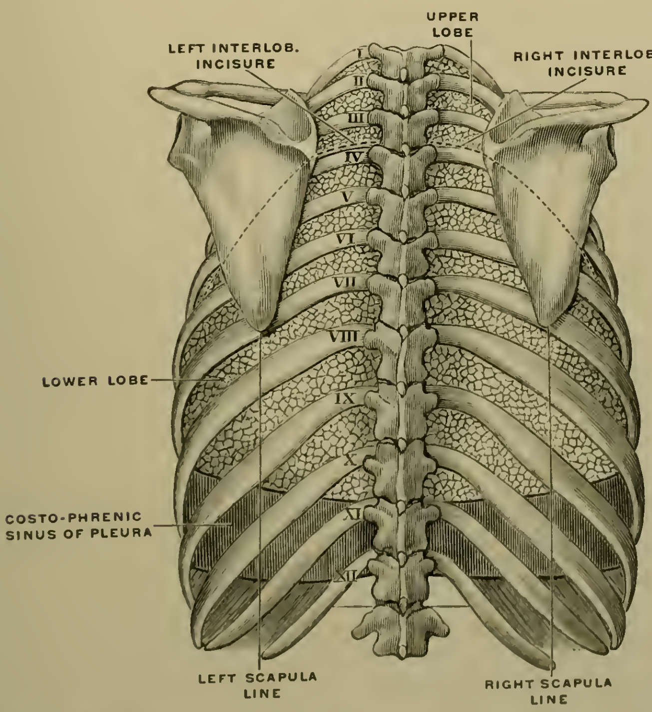
Position of the lungs and pleuræ with reference to the anterior chest wall. (Joessel.)

The **lower border** of the pleura, along which the costal and diaphragmatic surfaces meet, *reaches* the upper border of the seventh cartilage at the side of the sternum, the lower border of the seventh rib in the mammary line, the ninth rib in the axillary line, and the twelfth rib or eleventh thoracic spine at the side of the vertebræ. It may extend slightly below the inner end of the twelfth rib, occasionally even to the lower border of the first lumbar transverse process (Pansch), an important point in lumbar incisions to reach the kidney (see p. 315). Although the *left pleura* may extend somewhat *lower* than the right, owing to the liver on the right side, the difference in level is so slight that clinically it is not

worth considering. The **posterior border,** *extending* between the neck of the first and the head of the twelfth rib, is indicated in part by a ridge bounding posteriorly the groove which on the left side is formed by the aorta and on the right side by the azygos major vein.

Along the anterior and inferior borders the lungs do not reach as far as the pleuræ, but leave an interval or *sinus* where two layers of parietal pleura are in contact. The **costomediastinal sinus,** or that along the anterior border, is filled by lung in inspiration on the right side, but on the left side, opposite the cardiac incisure of the lung, a wide interval remains in the fullest inspiration, corresponding to the area of cardiac flatness, where the heart is uncovered by lung (costopericardial sinus) (Fig. 89).

Fig. 90



Position of the lungs and pleuræ with reference to the posterior chest wall. (Joessel.)

The **costophrenic sinus,** along the lower border of the pleura, is never filled on the deepest inspiration. The extent of the contact of the costal and phrenic portions of the pleura varies in different parts and on inspiration and expiration, and corresponds to the difference of level of the lower borders of the pleura and lung. In quiet breathing this sinus measures 2 cm. at the sternal and mammary lines, 2.5 cm. near the vertebræ, and 6 cm. in the axillary line (Luschka). Pathological fluids first collect here and can here be first diagnosticated. The presence of

the sinus explains the fact that a *wound* may penetrate the pleura and the diaphragm, and then enter the peritoneal cavity or the liver, without involving the lung. Unless we are sure that this sinus is full of fluid it is not safe to *puncture* the pleural cavity below the lower limit of the lung, though an *incision* may be carefully made at the lower limit of the pleura. The *lower limit* of the sinus is still quite a distance above the lower attachment of the diaphragm and the costal margin (about 5 to 6 cm. [2 to $2\frac{1}{2}$ in.] from the latter). The thin diaphragm alone separates the lower end of the pleuræ from the kidneys. The pleura is said to descend lower in the child. In children also the thymus separates the anterior borders of the pleuræ more widely than they are separated in the adult. The thick *costal pleura* is so connected with the endothoracic fascia by loose connective tissue that it is easily stripped up, while the *diaphragmatic pleura* is closely adherent.

Along the root of the lung the parietal (mediastinal) is continuous with the visceral pleura. Opposite and below the root of the lung the mediastinal pleura covers and is closely attached to the outer surface of the pericardium, with the phrenic nerve between, hence the latter may be affected by inflammation of either membrane.

The thin *visceral or pulmonary layer* of the pleura, besides covering and being closely adherent to the surface of the lungs, dips down into the bottom of the fissures, both surfaces of which it lines.

In pleurisy, or inflammation of the pleura, the opposing surfaces, pulmonary and parietal, are congested and then thickened and roughened by cell proliferation. The rubbing together of these roughened areas during inspiration causes the friction sounds and pain, hence the chest is strapped in pleurisy to prevent the movement of the lungs. If the opposed areas lose their roughness, become adherent, or are separated by fluid, the friction sound disappears. As the intercostal nerves supply the intercostal and other respiratory muscles as well as the costal pleura, the patient with pleurisy neither will nor can draw a deep breath on account of pain, hence breathing is shallow and the respiratory sounds weak. The pain may be referred to the abdomen, arm, etc., in the cutaneous distribution of the affected nerves. *Adhesions* may form between opposed roughened areas of the pleura. When *fluid* is extravasated this first accumulates in the costophrenic sinus, or posteriorly in the supine position. If the fluid is excessive the lungs are pressed backward and inward toward the hilum and the costovertebral groove, the intercostal spaces bulge, the surface veins are distended, and the heart is pushed toward the opposite side. In cases of "*pleurisy with effusion*" running a long course, the hyperplastic thickening may be very marked and the adhesions, when the fluid is removed, may be very extensive.

In *wounds* penetrating the pleura air may enter the pleural cavity, causing *pneumothorax*. If the opening is free, the pressure without and within the lung is balanced and its elasticity causes it to collapse and retract toward the hilum. In operating for empyema collapse of the lung is often prevented by its adhesions to the chest wall. If the opening of a wound of the pleura is not free, the respiratory movements may force

the air into the subcutaneous tissues, producing **subcutaneous emphysema.** Owing to the close contact of the visceral and parietal layers of the pleura, the latter can scarcely be wounded, except in the sinuses, without wound of the former. Pneumothorax or emphysema may also be caused by a ruptured vomica (or lung cavity) or by a wound of the lung such as is sometimes seen in fractured ribs, the air coming from the opened bronchi, etc. (see p. 231). Some non-penetrating wounds may also cause such an emphysema, the air being drawn in during one movement of respiration and forced into the tissues during another, the valvular nature of the wound preventing its escape. In *hemothorax*, or blood in the pleural cavity, there is usually a wound or lesion of the lung, but the blood can come in greater or less part from the vessels of the parietal wound.

THE LUNGS.

The two pyramidal-shaped lungs occupy about four-fifths of the thoracic cavity proper.

Position.—Contained in the two pleural sacs their **apices** correspond in position to the domes of the pleura which they completely fill. From the apices of the lungs the **anterior borders** (Figs. 89 and 90), which become thin and sharp about 4 cm. (1½ in.) below the apices, descend convergingly behind the sternoclavicular joints and nearly meet behind the sternum, opposite the second cartilages. Thence they descend vertically to the level of the fourth cartilages, a little to the left of the median line. In infants the thymus separates the anterior borders more widely, the right lung barely reaching the median line, while the left only reaches the left sternal border (Symington). From the level of the fourth cartilages the right lung bends slightly outward to reach the upper border of the sixth chondrosternal junction, while the left lung curves sharply outward, with an external convexity, across the fourth space and the fifth cartilage, and thence back nearly to the inner end of the sixth left cartilage, at the lingula. In expiration this "*cardiac incisure*" may reach to, or nearly to, the apex of the heart, which is covered by the lingula. It forms the left boundary of the area of cardiac flatness and the right border of the lingula of the left upper lobe.

The **level of the lower border** (Figs. 89 and 90) is especially important for the diagnosis of certain pulmonary conditions. In quiet breathing the lower border is at the upper border of the sixth costal cartilage at the side of the sternum, the upper border of the seventh rib in the mammary line, the lower border of the seventh rib in the axillary line, the ninth rib in the scapular line, the upper border of the eleventh rib or the tenth space at the vertebrae. It will thus be seen that the level of the lung at any line except the sternal is the same as the level of the pleura at the line next anteriorly (see p. 242). The left lung is said to be longer and extend lower than the right lung, but the difference is so slight, if it exists, that it is not worth considering from a practical clinical standpoint. In inspiration the anterior parts of the lung rise about equally with the elevation of the thoracic walls. At the sides, in deep inspiration, the lower

border descends about 3 to 4 cm. (1½ in.) (Godlee), in emphysema it is permanently lower, in the aged it is one-half to one intercostal space lower, and in children the same distance higher than in the adult. The difference in level of the lower border of the lung in extreme expiration compared with extreme inspiration is not over 6 cm. in the right axillary line, and 9 cm. in the left (Hasse). These borders in the axillary line do not reach nearer the lower margin of the chest than 7 and 5 cm. respectively. The **posterior border**, extending from the neck of the first rib to the eleventh rib, is usually taken to be the rounded part occupying the costovertebral groove, but, as stated above (see p. 243), it is better to consider it the ridge bounding the back of the groove for the aorta on the left and the azygos major vein on the right. To this border is attached the ligamentum latum, below the hilum. Normally the surface of the lung is everywhere in contact with the parietal pleura, which thus supports it, and it is further held in position by its attachment to the mediastinum by means of the root of the lung and the ligamentum latum.

Relations.—The **concave base** of the lung resting on the *diaphragm* is only separated by the latter and its serous coverings from the *abdominal viscera* in contact with it, liver, stomach, spleen, kidneys, suprarenals. Inflammation, abscess, and tumors of these organs, after penetrating the diaphragm, may involve the pleuræ and lungs, and vice versa. Liver abscess is occasionally evacuated through the lung and coughed up. On *percussion* we distinguish the lower border of the lung on the right side by the contrast between the pulmonary resonance and the liver flatness below it, and on the left side by the less marked contrast between the tympanitic resonance of the stomach and the pulmonary resonance. Internally the *heart* and many of the *great vessels* of the mediastinum are in relation with the lungs. The greater projection of the heart on the inner aspect of the left lung inferiorly makes the left lung, and especially its base, narrower than the right, and accordingly its bulk and weight are less. The left lung averages twenty ounces, the right lung twenty-two ounces in *weight,* but the weight may be greatly increased by disease. The *subclavian artery* grooves the forepart of the *apex* in a transverse direction.

The Fissures.—The fissures extend deeply toward the hilum. The *fissure* (Figs. 89 and 90) which separates the upper from the lower lobe commences on both sides at the posterior border 7.5 cm. (3 in.) below the apex, on a level with the third thoracic spine or the inner end of the spine of the scapula. Thence, sweeping around the convex surface of the lung, it meets the lower border in the mammary line on the right side, and at the outer end of the sixth cartilage on the left side. On the right side this fissure crosses the convex surface somewhat lower than on the left, and from about its middle, or where it crosses the posterior axillary line, a *second fissure* (Fig. 89) passes nearly horizontally forward to the fourth right chondrosternal junction, separating a *middle lobe* from the upper lobe.

Posteriorly, practically all the lung above the level of the inner end of the spine of the scapula is upper lobe; all below is lower lobe. *Laterally,*

in the axillary line, all the lung above the fourth rib on both sides belongs to the upper lobe, while on the left side all below belongs to the lower lobe, and on the right side from the fourth to the sixth rib belongs to the middle lobe, all below the sixth rib to the lower lobe.

Anteriorly, in the mammary line, on the left side all the lung above the middle of the fifth space belongs to the upper lobe, all below to the lower lobe; on the right side all above the fourth rib belongs to the upper, all below to the middle lobe. Thus we see that the lower lobe is not only below but behind the upper lobe. It is in the posterior part of the former that congestion and edema in old people, kept long supine, is likely to lead to "hypostatic pneumonia." These points are of practical importance in the *physical examination* of the lungs, especially when pneumonia or tuberculosis are suspected, for in the former the lower lobe and in the latter the upper lobe are most often involved.

The Apex.—The apex of the lung is a favorite site for *pleural adhesions* and for *tuberculous lesions.* The frequency of adhesions may be accounted for by the fact that the apex at all times fills the dome of the pleura, and, being a narrow portion of lung tissue, its motion is slight; and by the fact that the apex is frequently the seat of lesions which may lead to a pleurisy. In proportion to its bulk the apex probably expands as much as any other part of the lung, and the prevalence of tuberculous lesions here is to be accounted for by other factors than the stagnation of the air current in this part (see p. 248).

The concave *median surface* presents the oval fissure or **hilum,** where the structures contained in the **root of the lungs** emerge or enter. The upper end of the hilum is at the junction of the upper and middle third of this surface, opposite the disk between the fifth and sixth thoracic vertebræ, and at the junction of the anterior three-fourths with the posterior fourth of this surface. Hence the root of the lung is more accessible from behind. The neighborhood of the root of the lung, on account of the large vessels here, must be avoided in **puncturing the lung** with a needle for diagnosis. This may be safely done over the greater part of the anterior surface to the depth of 3.5 cm. ($1\frac{2}{5}$ in.) in a backward and outward direction. In puncturing the apical part from in front, through the first or second spaces, remember that the infernal mammary artery is a finger's breadth from the sternum and the axillary vein is 8.5 cm. ($3\frac{1}{2}$ in.) from the middle line in the first space and 11.5 cm. ($4\frac{3}{5}$ in.) in the second space.

The Color.—The color of the lungs changes from a reddish brown in the *fetus* to a pinkish white *at birth,* owing to their insufflation with air. In the *adult* they are slate-colored, with a darker mottling of certain lobules, which increases with age, is very marked in coalminers, etc., and is due to the deposit in the interlobular tissue of carbonaceous particles absorbed by the lymphatics. The **specific gravity** of the lungs is normally lighter than water, so that they float, but in certain diseased conditions (pneumonia, etc.) and in the fetus that has never breathed they sink. This fact is useful *medicolegally* to determine whether an infant was stillborn or born alive. If the child has breathed, the *weight*

of the lungs also increases by one-third (on account of the access of blood), the *size* increases, and the *consistency* is altered by aëration.

Capacity.—While the capacity of the lungs after the deepest inspiration averages 5000 c.c., 1500 c.c. of this (*residual air*) cannot be expelled by the fullest expiration. The total capacity minus the residual air, or 3500 c.c., is the *vital capacity* of the lungs, and is liable to be affected by various diseases of the lungs. In quiet breathing 1500 c.c. of "*reserve air*" remain after expiration in addition to the residual air, and in inspiration only 500 c.c. are breathed in, leaving 1500 c.c. of *complemented air* to be inspired by a forced inspiration.

Vessels.—The *bronchial vessels* supply the mechanism of the lung, or the lung stroma. They anastomose to some extent with the pulmonary vessels and so may be of service in stenosis or closure of the pulmonary artery, which is extremely rare. The **pulmonary artery** in its course to and through the lung is curved with an *upward convexity.* From the convex surface the first branch given off passes to the upper lobe and apex. Solid particles in the current which have a specific gravity greater than the blood tend to hug the upper wall and to pass into the first branch given off from this part. Thus they pass into the upper lobe and apex. This is the probable explanation of the more frequent occurrence of tuberculosis in the apex, especially as the tubercles are first observed in the walls of the smaller arteries at their points of bifurcation.

When a branch of the pulmonary artery is plugged by an embolus the circulation is stopped in the area supplied by it. This is called an *infarct* and is wedge-shaped, with the apex at the embolus and the base on the surface of the lung, for such is the shape of the area supplied by the vessel, whose circulation is terminal. If such an embolus is infective, an abscess may result. Only in the lung can the embolus come from a systemic vein, so that the lung is the most frequent seat (75 per cent.) of metastatic pyemic infarcts and abscesses.

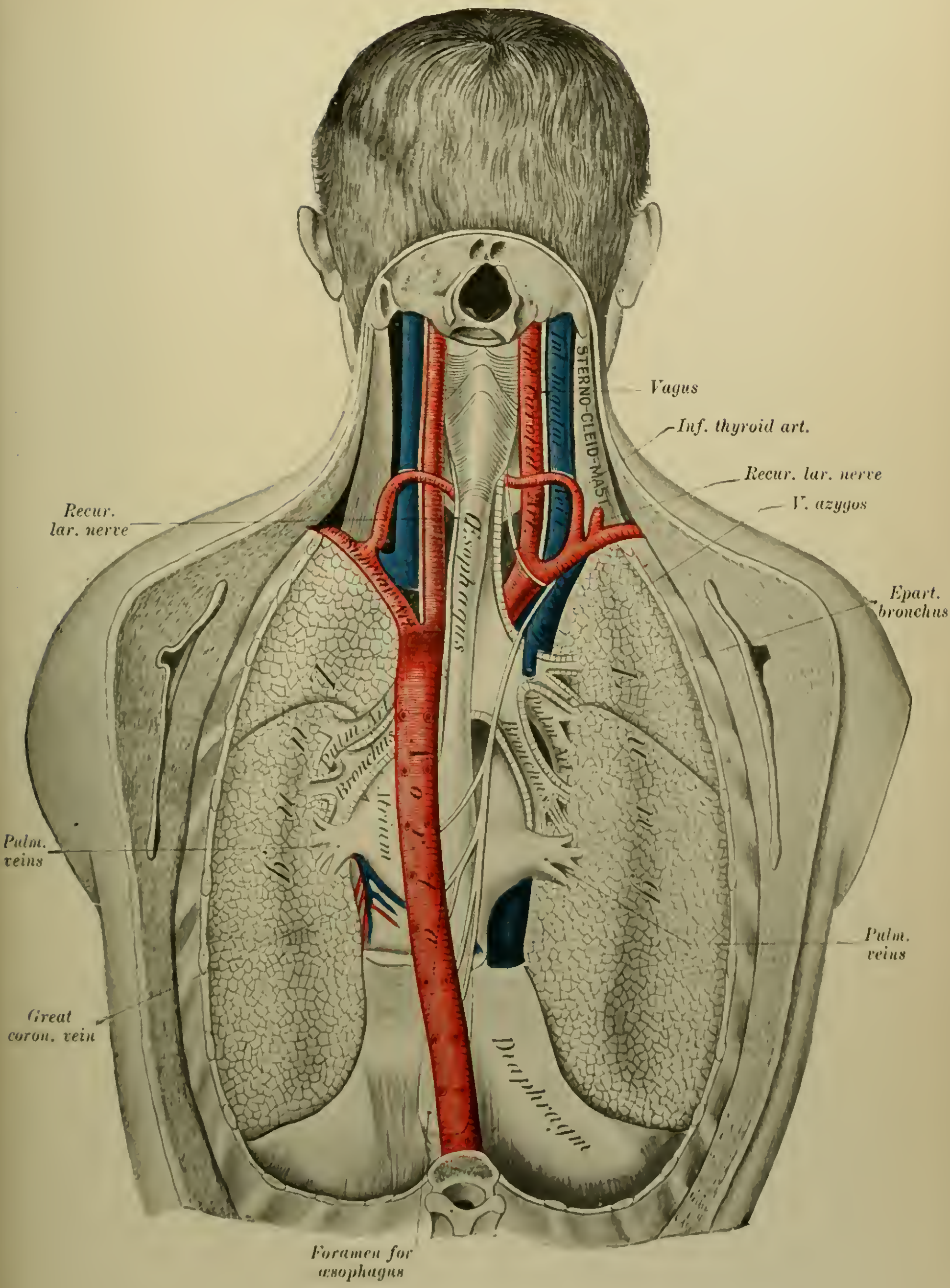
The **lymph vessels** of the lung empty into four or six nodes in the root of the lung which are accessory to the bronchial nodes. The root nodes are black from the pigment absorbed in the lungs. They are often diseased, and thus menace the neighboring parts.

In the **bronchi** the *muscular tissue* is arranged circularly, and by its reflex irritation from the vagus, as in indigestion, or by direct irritation in uric acid or uremic conditions, it may contract suddenly and give rise to an attack of *spasmodic asthma.* In chronic *interstitial pneumonia* the pull of the contracting new tissues draws apart the walls of the bronchi, as these offer less resistance than the retraction of the chest wall. Large bronchial cavities (*bronchiectasis*) are thus formed, in which the fluid collecting is liable to decompose and give rise to fetid breath and expectoration.

The sounds of breathing are mainly produced at the glottis like those of the voice. Hence, as we auscultate them through the chest wall, their loudness varies with the distance from the glottis. As the diameter of the tubes and the volume of air along which these vibrations are carried diminishes in the lung, the pitch becomes correspondingly higher. If the

PLATE XXIV

FIG. 91



Thoracic Contents Seen from Behind. (Joessel.)

breath sounds, normal in a given place (as over the large bronchi), are heard where they should not be heard, they become pathological. The pathological breath and voice sounds are often due to changes in the conducting power of the medium through which the sounds pass to reach the ear. Thus the sounds are diminished or absent if they traverse air or fluid in the pleural cavity, while consolidation of the vesicles increases the conduction, and the breath sounds in the bronchi are clearly heard (bronchial breathing), the voice sounds are loud and seem close to the ear (pectoriloquy), and the tremor of the vocal cords felt by the hand (vocal fremitus) is increased. The normal (vesicular) breath sounds are also diminished or lost when there is any obstruction or compression of the air passages, immobilization of the chest, etc. Rales follow the same rules as to loudness, but their quality varies, some being moist and due to the bursting of bubbles in mucous or watery secretion, others being dry (crepitant) and due to the separation of opposed surfaces which were glued together. They vary in fineness with the size of the passage where they are produced.

The **elasticity** of the lung is one of its striking and important features. It assists expiration, is one of the factors producing pigeon breast in the rachitic, explains the fact that in rupture or wound of the diaphragm the lung is never herniated into the abdomen, and it maintains the vault of the diaphragm. If the lung is wounded or incised within the limits of a pleural adhesion, subcutaneous emphysema may be produced, but not pneumo- or hemothorax. When the *pleural cavity is opened* through the thoracic wall, or through the lung, the atmospheric pressure within and without the lung is equalized, and hence it retracts, owing to its elasticity. In such cases we have a serosanguineous extravasation and air in the pleural cavity, and if the chest wall is injured, as by a fractured rib, subcutaneous emphysema is likely to occur. In operating on the thoracic cavity the collapse of the lung may be prevented either by diminishing the air pressure on the outside or increasing the pressure within the lung. **Hernia of the lung,** through a wound of the thoracic wall, can only occur when the lung fails to collapse, and this implies that the glottis was closed at the time of injury, that the wound was small, oblique, and valve-like, or that extensive adhesions bound the lung to the chest wall. In the latter case the adhesions would probably prevent hernia. The gravity of *wounds of the lung* depends largely upon the hemorrhage, hence they are more serious near the large vessels on the internal surface. Contusion and partial rupture of the lung may occur without fracture of the bony thorax. It is noteworthy that the air in pneumothorax seldom contains germs, or at least in sufficient number to infect the extravasated blood. Wounds of the lung cicatrize rapidly and the air in the pleural cavity is rapidly absorbed. Blood expectorated from the lungs is necessarily coughed up and mixed with air, hence it is frothy and bright red. It is also alkaline, while that retched up from the stomach is acid and dark.

Roots of the Lungs (Fig. 91). In the root of the lung the *bronchus lies* posteriorly with the artery and vein in front, and the latter below. Hence when an object is impacted in the main bronchi or their primary

divisions they may best be *reached from behind* by a posterior thoracotomy, an opening into the thorax at the side of the vertebræ at the level of the fourth to the seventh ribs. In this operation it is well to remember that the space between the tips of the transverse processes and the angles of ribs varies from 2.5 to 6 cm. (1 to $2\frac{1}{2}$ in.), and that the tips of the spinous processes of the second to the eleventh thoracic vertebræ correspond to the level of the heads of the ribs corresponding in number with the vertebra next below (Bryant). *The relations* of the roots of the lungs are important in such cases. On the right side the azygos major vein is behind and arches above it, to open into the superior cava; while on the left side the arch of the aorta is above and the descending aorta and esophagus behind it. On both sides the pneumogastric nerve and the larger or posterior pulmonary plexus are behind, and the phrenic nerve and the smaller or anterior plexus in front. Hence the left side is more covered by important relations and is more difficult to reach, but the pleura is retracted with more difficulty on the right side, making it less easy to reach. By stripping back from the mediastinial side the pleura covering the posterior aspect of the root we expose the bronchi. These are easily recognizable by touch on account of the cartilaginous rings, and may then be opened (bronchotomy). The root of the lung measures 3 cm. vertically and 2 cm. anteroposteriorly; the right root is larger, the left longer.

THE THORACIC PORTION OF THE TRACHEA.

This *extends* from the episternal notch, at the level of the disk between the second and third thoracic vertebræ, to its bifurcation, opposite the disk between the fourth and fifth thoracic vertebra, and includes about half the length of the tube, or 5.5 cm. ($2\frac{1}{4}$ in.) It *lies* in the superior mediastinum between the two pleural sacs and the vagus nerves, in front of the esophagus, and behind the remains of the thymus gland, the left innominate vein, the innominate and left common carotid arteries, and the arch of the aorta. It *bifurcates* behind the lower border of the aortic arch at about the level of the junction of the first and second pieces of sternum, or of the inner end of the spine of the scapula. Hence abnormal sounds produced at the tracheal bifurcation, or in the primary bronchi, can best be heard between the shoulders at this level. Surrounding the bifurcation of the trachea are twenty to thirty *bronchial lymph nodes,* which are frequently diseased and may press upon and narrow the trachea or adhere to and ulcerate through it. Stenosis of the trachea from syphilitic lesions or from aneurysms of the aorta or the great vessels are apt to occur at its upper or lower ends, respectively. Compression of the trachea is more serious in the chest than in the neck, for in the former it cannot escape or avoid the effects of even moderate pressure.

Of the two **bronchi** *the right* is the larger, so that the dividing ridge (carina tracheæ) between the two bronchi lies to the left of the median line, and it is more vertical so that the trachea seems to lead more directly

into the right bronchus. Hence, and by reason of the greater intake of air, foreign bodies are more likely to pass into the right bronchus, and, as we have already seen, this is the side most safely exposed from behind. If small enough, they may pass on into the secondary bronchi with the same inspiration with which they passed the glottis. Such foreign bodies cause a mechanical obstruction of the air passages and also a reflex spasm of the glottis, together with cough, dyspnea, alteration of voice, etc. Foreign bodies at or a little below the bifurcation of the trachea may often be removed by forceps introduced through a low tracheotomy opening, or they may be spontaneously expelled by a fit of coughing through the open tracheal wound or through the larynx. They may also be removed, even from the secondary bronchi, by the aid of the bronchoscope. In other cases they have caused an abscess of the lung, or have ulcerated through the bronchus and been discharged through an abscess at the back, adhesions having shut off the pleura. Mr. Godlee records a case where a head of rye so escaped.

The *course* of the bronchi is toward the hindpart of the lower surface of the lung (*i. e.*, behind the axis of the lung). Hence, of the ventral and dorsal branches given off by the bronchi, the former are much the larger. The *relation* of the left stem bronchus to the aortic arch, which arches above and then behind it, explains the frequent pressure of *aneurysms* on this bronchus. The close relation of the aortic arch to the bifurcation of the trachea explains the sign known as "tracheal tugging" elicited with the patient erect, the chin elevated, and the mouth closed, by steady and gentle upward traction on the cricoid. If pulsation is distinctly transmitted to the hand, aneurysm or dilatation of the aorta is indicated. The right undivided bronchus averages 2.5 cm. (1 in.) in *length*, the left 5 cm. (2 in.). The latter enters its lung 2.5 cm. (1 in.) lower than the right, opposite the sixth thoracic vertebra.

THE PERICARDIUM.

The pericardium, like the pleura, is a closed invaginated sac. But it is more complicated than the pleura, for instead of one there are seven reflections, which connect the parietal and visceral layers and form more or less complete sheaths around the great vessels at the base of the heart. Between these sheaths there are a number of pouches or sinuses, of which the largest is the great or *transverse sinus*, between the auricles behind and the tubular sheath of the aorta and pulmonary artery in front. An encapsulated effusion may occur in this sinus, the pressure of which is exerted principally upon the thin-walled superior vena cava, without giving evidence of pericarditis with effusion. Sinuses like those of the pleura exist only to a slight extent at the reflection of the pericardium from the diaphragm. The tubular pericardial sheath common to the aorta and pulmonary artery is the only complete one among the seven. It covers the proximal 3.7 cm. (1½ in.) of these vessels, which is, therefore, within the pericardial sac. The *parietal serous layer* is reinforced exter-

nally by a *fibrous layer*, which blends with the outer coat of the great vessels beyond their serous investments and becomes continuous above with the deep cervical fascia. Hence the pericardium is connected with the respiratory muscles of the neck, like the omohyoid, above, as well as with the diaphragm below, so that in a full inspiration it is pulled upon from both directions and made tense and resistant to the pressure on the heart by the inflated lungs.

The **elasticity** of the parietal pericardium allows it to be *stretched* to double its size, so as to contain twelve to eighteen ounces in case of acute **pericardial effusion,** or even up to three pints in chronic cases. It is only when the pericardium is greatly distended that the pressure affects the heart, especially in diastole, and may cause a fatal result. As the *shape* of the pericardium is cone- or pear-shaped, with the base below on the diaphragm and the apex above, this is the shape of pericardial effusions, while in cardiac hypertrophy or dilatation the long diameter is directed transversely. In pericardial effusion the *dulness* reaches beyond the apex beat, or, if the effusion is extensive, the apex beat may not be perceptible. When the *sac is but partly full*, the fluid, and with it the area of dulness, may shift its position with that of the body, and, as it presses upon the bronchi in the reclining position, the patient breathes more easily in the upright posture. By *excessive pericardial effusion* the lungs, especially the left, are pushed aside and compressed laterally, increasing the area of heart dulness, the diaphragm, liver, and stomach are displaced downward, the lower two-thirds of the sternum and the corresponding left cartilages and spaces are bulged forward, and the trachea, left bronchus, and esophagus are compressed posteriorly, giving rise to cough, dyspnea, and dysphagia.

Paracentesis of the pericardium is usually *done* in the fifth left space 2.5 cm. (1 in.) from the sternum. If a point nearer the sternum is taken there is danger of wounding the internal mammary artery (p. 233), though if an incision is used and not a puncture, we may go close to the sternum. Unless the pleura has been pushed aside by the effusion, the trocar will puncture two layers of it 2.5 cm. (1 in.) from the sternum. The puncture may preferably be made in the sixth left space with less danger of wounding the heart, and if made close to the sternum the danger of wounding the mammary artery is avoided. Some advise puncturing on the right side of the sternum in the fourth or fifth space, where the distended pericardium also bulges, on the supposition that there is less danger of puncturing the heart itself.

Normally the pericardium is in direct *relation* with the anterior parietes (sternum) only (1) over a small area at its upper end, where it is reflected onto the aorta, and (2) over a triangular area at the lower end of the sternum, where the pleuræ diverge, and where, by a trephine opening, the pericardium, uncovered by pleura, may be reached. No true ligaments, only loose connective tissue, bind the pericardium to the back of the sternum. Whereas in front and laterally the pericardium is largely covered by pleura, the phrenic nerves intervening laterally, *posteriorly* it forms the anterior boundary of the posterior mediastinum, and is in direct

relation with the thoracic aorta, azygos veins, thoracic duct, and esophagus, which pericardial effusion may press upon, especially in the supine position.

THE HEART.

On opening the pericardium in front we see the anterior or **sternocostal surface** of the heart, comprising a part of the two ventricles, the right auricle and its appendage, and the tip of the left auricular appendage. Of these parts, the *right ventricle* presents the greater area, hence it is most often *wounded* in wounds of the heart. As the **right ventricle** is one-third the thickness of the left, we can tell the two apart by the feeling. The **left ventricle** is thinnest at the apex and thickest at the junction of its upper and middle thirds. The anterior and posterior *interventricular grooves* lie near the left and inferior borders respectively, and meet and are continuous to the right of the apex.

In *front* the heart is *overlapped* by the pleuræ, except behind the lower end of the sternum, as described above (p. 242), and by the thin margins of the lungs, except for this area between the pleuræ and that of the cardiac incisure, which corresponds to the **area of cardiac flatness**. The latter corresponds to a *triangular area* bounded below by the lower border of the heart, on the right by the left sternal margin up to the upper border of the fourth cartilage, and on the left by a line curved outward from the latter point to the lower border near the apex. A *circle* 5 cm. (2 in.) in diameter, with its centre midway between the nipple and the sternoxiphoid junction, would also approximately represent this area. Emphysema may cause this area to be much diminished.

The anterior or sternocostal surface is the only one accessible to clinical investigation by percussion, etc. Besides the area of cardiac flatness, we have the *area of cardiac dulness*, which corresponds to that part of the anterior surface overlapped by the lungs and sternum. Owing to the modification of the percussion note by the sternum and the margin of the right lung, the *right border* of the heart cannot be definitely determined. As the heart dulness merges into that of the liver below, the *lower border* cannot be determined by percussion, but may be constructed by continuing the lower border of the right lung through the sternoxiphoid junction to the apex of the heart. The *left border* alone is tolerably accessible to percussion, and by this we determine changes in the size and position of the heart.

Laterally the heart is in contact with the lungs, separated by the pericardium, pleuræ, and phrenic nerves. It encroaches more on the left side of the chest and the left lung, so that two-thirds of the heart are on this side. Only the right auricle and a small part of the left auricle and right ventricle are on the right side of a median sagittal plane. The auricles lie above, behind, and to the right of the mass of the ventricles, and correspond to the sixth, seventh, and eighth thoracic vertebræ. But between the heart and the thoracic spine lies the posterior mediastinum, containing the esophagus, thoracic duct, aorta, and azygos veins.

The **apex**, belonging solely to the left ventricle, is directed downward, forward, and to the left, and strikes the chest wall in systole in the fifth space 8 cm. ($3\frac{1}{4}$ in.) from the median line, or 5 cm. (2 in.) below and 2.5 cm. (1 in.) internal to the male nipple. The *apex beat* may be likened to the recoil of a gun, due to the discharge of blood into the aorta. It also depends upon the lengthening of the aorta from the blood entering it at the cardiac systole.

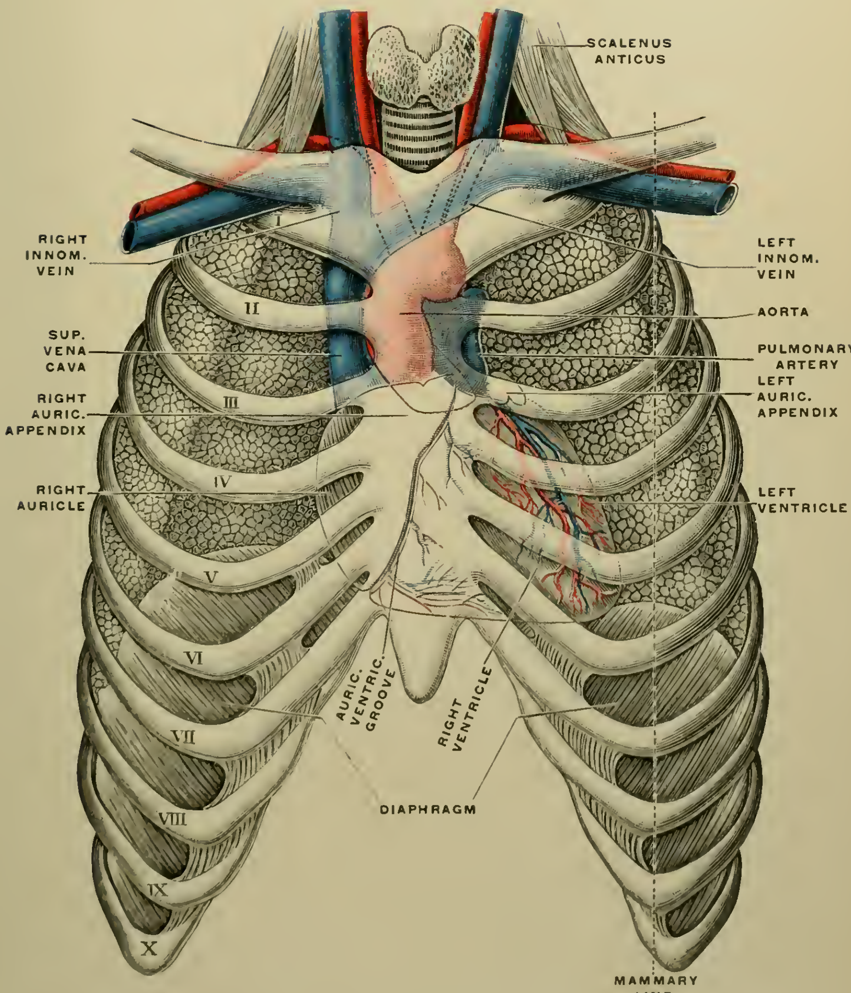
Topography.—The heart, as projected onto the chest wall, **may be mapped out** as a *triangular figure,* whose upper truncated angle represents the **base** of the heart, from which the great vessels are given off. This is represented by a line across the sternum at the level of the upper borders of the third cartilages, somewhat higher on the left than on the right, and projecting 12 mm. ($\frac{1}{2}$ in.) to the right and nearly 2.5 cm. (1 in.) to the left of the sternum. The **lower border,** margo acutus, formed by the right ventricle, is drawn from the apex to the junction of the sixth (or seventh) right costal cartilage with the sternum, crossing the sternum near the costoxiphoid junction. This line is nearly horizontal behind the sternum, slightly convex downward to the left of it. The **left border,** margo obtusus, formed by the left ventricle, and the **right border,** formed by the right auricle, are completed by lines convex laterally, which connect the left and right ends of these two lines, representing the base and the lower border. The right border projects one to two fingers' breadth from the right sternal margin, or 3.7 cm. ($1\frac{1}{2}$ in.) from the middle of the sternum opposite the fourth space.

The **auriculoventricular groove** runs from the third left to the sixth (or seventh) right chondrosternal junction. The **pulmonary orifice** is the most superficial. It *lies* behind the sternal end of the left third costal cartilage, but the sound of the closure of the valve is transmitted upward with the blood stream and is heard most plainly in the second left space, close to the sternum. The **aortic orifice** is a little below and to the right of the latter, behind the left half of the sternum, opposite the third space. The **mitral orifice** is just to the left of and behind the latter, behind the left border of the sternum, and opposite the third space or the fourth cartilage. Notwithstanding the close proximity of these two most important valves of the left heart, there is clinically no difficulty in distinguishing their respective *sounds,* for they are transmitted in the line of the blood stream, so that the sound of the mitral closure is best heard near the apex of the heart, that of the aortic at the sternal end of the second right intercostal space. The points of greatest intensity of the valvular sounds are much more superficial than the valves themselves, especially the mitral valve, which lies farthest posteriorly, behind and a little to the left of the aortic valve. The **tricuspid valve** lies behind the middle of the sternum about the level of the fourth space.

The first sound of the heart occurs during ventricular contraction (systole), and is due to the closing of the mitral and tricuspid valves and perhaps to the impulse of the apex beat. The second sound is due to the closing of the aortic and pulmonary valves, during the filling of the auricles and ventricles (diastolic). Of the pathological sounds or

PLATE XXV

FIG. 92



Relation of Heart and Great Vessels to the Anterior Chest Wall.
(Joessel.)

murmurs, one heard before the first sound (presystolic) is due to a stenosis of one of the auriculoventricular valves, which makes the passage of blood difficult. A murmur heard with the first sound, or with the radial pulse (systolic), is due to insufficiency with reversed flow through the mitral (or tricuspid) valve, or to stenosis of the aortic (or pulmonary) valve. One heard with the second sound (diastolic) is due to a regurgitation at the aortic (or pulmonary) valve. The murmurs of aortic and mitral insufficiency are the most common; 90 per cent. of all cases of disease of the valves occur in those of the left side, for more work is required of this side, with the danger of greater strain.

Displacements of the Heart.—The *position* of the heart *varies* slightly with its systole and diastole and with the position of the body. In *children* the apex is often higher (fourth space), in *the aged* lower, (sixth space), than the position given above. The heart is *elevated* in case of ascites, tympanites, or tumors of the abdomen which raise the diaphragm, and *depressed* in case of effusion into the pleural cavity, emphysema, large aortic aneurysm, mediastinal tumors, and cardiac hypertrophy and dilatation (left ventricle). If the effusion is on one side only, the heart is *displaced to the opposite side.* Effusions on the left side may displace the apex to or beyond the right margin of the sternum and dislocate the heart to such an extent as to disturb the circulation. The heart may also be *pulled* to either side by a contracting lung or pleural adhesion. The *descent* of the heart *in inspiration*—about 2.5 cm. (1 in.)—is not as great as it is made to appear by the elevation of the ribs in front of it. In cases of *transposition of the viscera* the apex beat is found on the right side, and the position of the heart is correspondingly altered. The heart's position is affected by its *enlargement,* which causes lateral displacement, as a rule. This enlargement is usually at first of the nature of a dilatation, and then the walls begin to thicken or hypertrophy to compensate for the dilatation. Hence, for instance, an aortic obstruction, that may be the cause of the dilatation, may be of comparatively little importance if there is compensatory hypertrophy of the left ventricle. The ill effects on the heart in valvular heart disease always extend in the opposite direction to that of the blood stream.

Increased resistance and distention cause dilatation, and increased work, to overcome the resistance, causes hypertrophy of the heart as of any other muscle. The increased resistance is most often due to arteriosclerosis, increased arterial tension, and valvular disease of the heart.

The *right and left coronary arteries* supplying the heart *run* in the auriculoventricular and interventricular grooves. Those in the grooves on the anterior surface are especially exposed to injury in wounds of the heart. There is no direct anastomosis between the branches of these vessels. *Atheroma* of these arteries causes a poor blood supply of the heart, which may result in fatty or fibroid degeneration of the heart muscle, or in angina pectoris. These changes in the heart muscle predispose to *rupture of the heart,* often from some strain or injury. This occurs in the order of frequency in the right auricle, left ventricle, left

auricle, etc., owing to the relative weakness or the greater tendency to degeneration of the myocardium. An *embolus* in one of the coronary arteries may cause sudden death from paralysis of the heart muscle.

The *size* of the heart is, roughly speaking, that of the closed fist; the *weight* varies greatly, averaging 266 to 292 grams. The size and weight of the heart increase up to advanced life, and are one-sixth less in the female. A physiological hypertrophy, especially of the left ventricle, occurs in pregnancy.

Wounds of the Heart.—Wounds of the heart most often involve the anterior surface, and hence concern the right auricle and ventricle and the left coronary artery and its accompanying vein, in the anterior interventricular groove. Wounds in the third, fourth, and fifth spaces close to the right of the sternum are liable to injure the *right auricle*, those in the same spaces to the left of the sternum the *right ventricle*. The *superior vena cava* may be wounded by a stab wound in the first or second right interspace close to the sternum. Wounds of the auricles are more serious and more rapidly fatal than those of the ventricles, owing to the thicker walls of the latter and their capacity to contract and prevent the escape of blood. For a similar reason wounds of the right ventricle are more serious than those of the left. Wounds of the ventricles may be followed by little or no hemorrhage, owing to the contraction of the muscle fibers, which run in all directions, and the resulting closure of the wound. Owing to the position of the pleura and its relation to the pericardium, a wound of the normal heart, unless it penetrates the sternum at certain points, must also pierce the pleura, hence blood is apt to be found in the left (more rarely in the right) pleural cavity. Wounds of the normal heart, except over the area of cardiac flatness, involve also the anterior margin of the lung, hence air may escape into the pericardial as well as into the pleural cavity, and the blood is frothy. Wounds of the heart are not necessarily fatal, and fatal wounds are not as instantly fatal as commonly supposed. If death occurs at once, it is usually due to interference with the heart's action by the presence of blood which has escaped into the pericardium, and not to the effect of the injury on the cardiac nerve centres. Patients with apparently fatal cardiac injuries have lived for some time, and others have survived to die of other causes. In a few cases the foreign body causing the injury has been found on postmortem encapsulated within the heart muscle. Punctured wounds of the ventricle, especially of the left ventricle, may be recovered from. Needles have not infrequently been found embedded in the heart muscle, having worked their way there from a nearby situation. *Operations* for cardiac injuries afford a better prognosis than expectant treatment. Of reported operations for wound of the heart, 40 per cent. have recovered. The heart is exposed by dividing the costal cartilages from the sixth to the third close to the sternum and turning the flap of chest wall back to the left. The pleura is separated from within outward from the pericardium, which may then be opened. Through such a wound cardiac massage to resuscitate desperate cases of syncope during anesthesia has been used of late.

THE AORTA.

The first or *ascending portion* of the aorta *extends* upward, forward, and to the right in the axis of the heart. It *lies* behind the sternum and passes from the aortic orifice, behind the left half of that bone, opposite the third space, to the upper border of the right second chondrosternal junction. It reaches to within about 1 cm. of the root of the innominate artery, and lies *within the pericardial sac*, covered by the sheath of the serous pericardium common to it and the pulmonary artery. Hence an *aneurysm* of this part, before it attains a large size, very commonly bursts into the pericardium, causing sudden death.

The relations of the aorta are of importance in connection with the pressure symptoms of aneurysm of its different parts. **Aneurysm,** so common in the aorta when its walls are affected by disease, is most likely to involve the ascending part, for this is not strengthened, like the arch, by the fibrous layer of the pericardium blending with it. Moreover, it is the first part to receive the impulse of the cardiac systole. This impulse is felt especially along its right anterior aspect, where there is a normal bulging of the wall, the *great sinus* of the aorta, from which the current is reflected, as it were, toward the left into the arch. **Aneurysm of the ascending portion** usually bulges to the right and forward. Hence it presses on the superior cava *on the right*, causing congestion of the head, upper extremities, and chest wall, which may result in lividity, swelling, and edema of these parts, and in dizziness and headache. It presses on the sternum *in front*, from which it is normally separated by the overlapping right lung and the remains of the thymus gland. The *pulsating tumor* first appears in the second right space, but after erosion of the sternum this and the upper right cartilages may bulge forward. If the tumor is *directed backward* it may press upon the right pulmonary artery, which lies behind it, or on the right bronchus behind the artery, causing a deficient blood and air supply to the right lung and consequent dyspnea. Again, the aneurysm may start from one of the *sinuses of Valsalva*, usually the right or anterior one, as the regurgitation of blood after systole occurs particularly here. Such a tumor, usually sacculated, projects chiefly forward and to the right, pressing on the pulmonary artery in front and the right auricle and superior vena cava on the right. The *great sinus* of the ascending aorta projects a slight and varying degree to the right of the sternum, depending partly on the breadth of the sternum, and might be *wounded* in the right second space.

The Arch of the Aorta.—The arch of the aorta is badly named the transverse portion of the arch, for its *principal direction* is backward, from about 6 mm. (¼ in.) behind the sternum, at the second right chondrosternal junction, to the left side of the body of the fourth thoracic vertebra. Its *transverse course* corresponds only to about the width of the sternum. The downwardly directed concavity or *lower border* corresponds to the junction of the manubrium and body of the sternum. It is also concave to the right and posteriorly. Its convexity or *upper*

border corresponds to the level of the third thoracic spine, the middle of the first costal cartilages, the middle of the manubrium, or a point about 2.5 cm. (1 in.) below the episternal notch. In feeble and small-chested persons it may reach nearly to the top of the sternum, or in big-chested men it may occasionally lie as much as 4 to 6 cm. ($1\frac{1}{2}$ to $2\frac{1}{2}$ in.) below it. It is **covered in front** by the margins of the right and left pleuræ and lungs, and between their diverging margins by the remains of the thymus gland. Toward the left side the left vagus and phrenic nerves cross in front of it. The *left recurrent laryngeal nerve* arches beneath and then behind it, just to the left of the remains of the ductus arteriosus, which connects the arch inferiorly with the angle of bifurcation of the pulmonary artery, or the root of its left branch. The *root of the left lung,* including the left bronchus, pulmonary artery, etc., lies **below it. Behind it** is the lower end of the trachea, just above or at its bifurcation, the esophagus, thoracic duct, and the left recurrent laryngeal nerve. Its **upper border** is overlapped by the left innominate vein, which covers the roots of its three branches which are given off above, from its convexity.

A consideration of these *relations* will indicate the *pressure symptoms* of an aneurysm, which depend upon its position and the direction of its extension. The most common *situation* is on the *posterior or right aspect,* where it may *press upon* the *trachea,* causing dyspnea, cough, and harsh breathing, and on the *left recurrent laryngeal nerve,* paralyzing the left vocal cord, altering the voice and so simulating laryngitis that tracheotomy has sometimes been done. Owing to its pressing more heavily upon the trachea in the reclining position, the patient may be unable to lie down with comfort. Extending farther backward it may press upon the *esophagus,* causing dysphagia and simulating esophageal stricture, upon the *thoracic duct,* causing inanition, or upon the sympathetic nerve, causing dilatation of the pupil from irritation, and then contraction of the pupil from paralysis of the ciliospinal fibers. *Extension forward* would involve the sternum, cause its erosion, and give rise to a pulsating bulging tumor, or press upon the left vagus or phrenic nerves. In case of *extension downward* the pressure may impede the circulation through the pulmonary artery, and especially its left branch, causing dyspnea or even cyanosis from the scanty oxidation of the blood. It may obstruct the left bronchus, causing cough, dyspnea, and left-sided harsh and diminished breathing, or it may affect the left recurrent laryngeal nerve. *Upward extension* of the tumor causes pressure on the *left innominate vein,* resulting in serious congestion of the left side of the head and neck and the left upper extremity, or upon one or more of the *primary branches* of the aorta, compressing or even obliterating them, and causing inequality of the carotid or radial pulses on the two sides, or absence of them, especially on the left side.

The tumor may extend up into the root of the neck, resembling aneurysm of the innominate, left carotid, or subclavian arteries, and cause difficulty in diagnosis. Aneurysms of the ascending aorta and the arch of the aorta are liable to lower the heart and to disturb the heart's action by pressure upon the cardiac plexuses. They may *rupture* into any of

the cavities or hollow tubes with which they are in contact, causing a sudden fatal hemorrhage. The *percussion note* may be dull over a considerable area, owing to displacement of the lungs laterally.

Most descriptive text-books speak of a short third or descending portion of the arch, but there is no sufficient reason for separating this from the **descending thoracic aortic**, which extends from the fourth thoracic vertebra to the aortic orifice of the diaphragm, opposite the twelfth vertebra and slightly to the left of the median line (Joessel). Superiorly it *lies* to the left, inferiorly in front of the *thoracic spine*, superiorly to the left and inferiorly behind and to the right of the *esophagus*, and superiorly to the left and at its lower part in front of the *thoracic duct*. Furthermore, it passes behind the root of the left lung, grooves this lung just in front of its posterior border, and lies behind the pericardium and to the left of the vena azygos major. **Aneurysm** of this part may *press upon* and obstruct any of the above-mentioned parts, erode the spine and the vertebral ends of the left middle ribs, cause pressure upon and neuralgia of the corresponding left thoracic nerves, and bulge posteriorly to the left of the spine as a pulsating tumor, sometimes of enormous size. It may even cause compression of the cord and paralysis. It may eventually *rupture* on the surface or into the esophagus, left bronchus, pericardium, pleura, or posterior mediastinum.

Variations.—The arch of the aorta is liable to occasional variations in its position and direction, with or without transposition of the viscera, and to frequent variations in the *number and arrangement of its primary branches*. These variations may decrease the number of primary branches to two, or increase them to four, five, or six.[1] These anomalies are to be *explained by* abnormalities in the *embryonic development* of these parts from the ventral and dorsal stems and the branchial vessels. The only variation of much surgical interest is the origin of the *carotid*, usually the *left, from the innominate stem* of the opposite side, in which cases it may cross the trachea so as to be in danger of injury in a low tracheotomy. Not infrequently the *right subclavian* arises from the left end of the arch and passes behind the trachea and esophagus to reach its normal position.

The *innominate* and *left common carotid*, given off immediately behind the middle of the manubrium, mount thence to the right and left sterno-clavicular joints, the former artery dividing opposite the upper border of the right joint. The *innominate artery*, 4 to 5 cm. ($1\frac{1}{2}$ to 2 in.) long, has the left innominate and the right inferior thyroid veins in front; the right innominate vein, pneumogastric nerve, pleura, and lung to the right; the trachea behind and to the left, and the left carotid artery to the left. These most important *relations*, and the occasional (10 per cent.) origin from it of the thyroidea ima artery, are of importance in the *diagnosis of aneurysm* of this artery from the pressure symptoms, and in its **ligation** for aneurysm of its branches, several successful cases of which are now

[1] For the above variations see Henle's Anatomy, 1886, vol. iii, pp. 203 et seq., or any descriptive anatomy

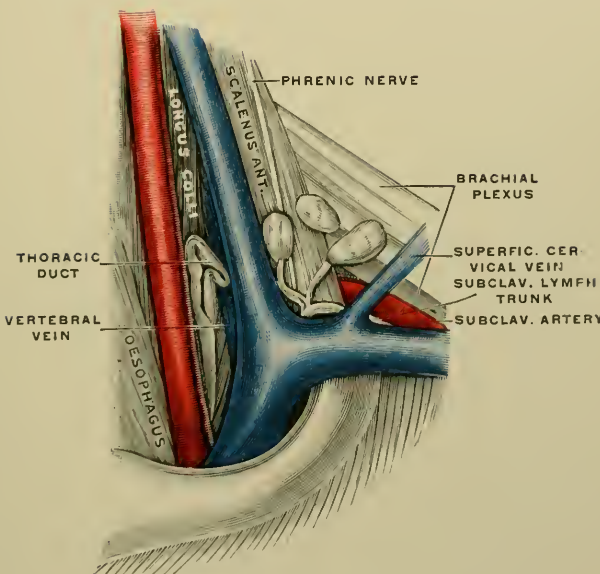
on record. The chief pressure symptoms are weakness or absence of the radial or carotid pulse; cyanosis and edema of the arm, neck, and face, especially of the right side; cough and hoarseness (recurrent laryngeal); dilatation or contraction of the right pupil (sympathetic nerve); hiccough (phrenic nerve); dyspnea and dysphagia. The dangers of the operation itself lie in the important structures in relation with it and in the difficulty of an adequate *exposure,* which may be facilitated by osteoplastic resection of the manubrium (Bardenheuer), or better by a longitudinal median section of the sternum, or its upper half, and the lateral retraction of the divided edges, which exposes the mediastinum and its contents. The simultaneous ligation of the right common carotid and vertebral lessens the risk of secondary hemorrhage distal to the ligature.

The **pulmonary artery,** in its course from the third left to the upper border of the second left chondrosternal junction, projects more or less beyond the left border of the sternum in the second space, where it is exposed to injury. Similarly on the right side the **superior vena cava,** from its origin behind the sternal end of the first costal cartilage to its termination behind that of the third cartilage, lies just to the right of the sternum and ascending aorta, and is exposed to injury in the mesial ends of the first and second spaces. The **left innominate vein** crosses transversely behind the manubrium, just above the aortic arch and just below the episternal notch, and in children and in cases of great venous congestion or of high position of the aortic arch it may project above the sternum, so as to be exposed to injury in a low tracheotomy or in some thyroidectomies. The **azygos veins** are of practical importance on account of the free *collateral circulation* they afford between the inferior and superior cavæ, in case of obstruction of the former. This is due to their connection with the lumbar, iliolumbar, common iliac, and renal veins.

The **great, small, and least splanchnic nerves,** derived from the fifth to the ninth, the tenth to the eleventh, and the twelfth thoracic sympathetic ganglia respectively, are connected with the correspondingly numbered thoracic nerves, which also supply the abdominal parietes. Thus the same segments of the cord supply the abdominal viscera and the skin and muscles covering them. As the splanchnic nerves pass to the solar, renal, and other plexuses which supply the abdominal viscera, they *account for* the *reflexes* between the abdominal viscera and the parietes (see p. 281), and for the pain in some diseases of the liver and stomach, in the region between and over the scapulæ, supplied by the dorsal branches of the thoracic nerves which are connected with the splanchnics. *Pressure of thoracic tumors or aneurysms upon the sympathetic* may cause dilatation of the pupil of that side, from irritation of its ciliospinal fibers, or contraction of the pupil, from their paralysis. As these fibers leave the cord by the first thoracic and eighth cervical nerve roots, the pressure must be exerted at the upper end of the thorax to produce these pupillary symptoms. As some filaments of the **right phrenic nerve** pass to the solar plexus and the liver, the pain over the tip of the right shoulder in liver disease may be explained as a reflex in the supra-acromial filaments from the third, fourth, and fifth cervical nerves, from which the phrenic is derived.

PLATE XXVI

FIG. 93



Topography of the Thoracic Duct in the Neck. (Zuckerkandl.)

THE THORACIC DUCT.

This is about 45 cm. (18 in.) *long* from its commencement in the abdomen in the *receptaculum chyli*, opposite the second (or first) lumbar vertebra, to its termination in the neck, in the posterior part of the angle of union of the subclavian and internal jugular veins. It is mostly contained within the thorax. Here, after passing through the aortic opening of the diaphragm behind the aorta, it lies between the latter and the vena azygos major, in the *posterior mediastinum*, up to the level of the fifth thoracic vertebra, where it inclines to the left behind the esophagus, the aortic arch, and the left common carotid artery. Thence in the *superior mediastinum* it lies between the esophagus and the left pleura, behind the left subclavian artery, and in front of the vertebral artery. After ascending through the superior thoracic aperture into the *left side of the neck* as high as the seventh cervical vertebra it arches outward, forward, and downward over the apex of the pleura, in front of the subclavian artery, the scalenus anticus muscle, and the vertebral vein, and behind the left internal jugular vein and carotid artery, becoming external to the latter (Fig. 93).

The *highest point* of the arch of the thoracic duct normally reaches the level of the transverse process of the sixth cervical vertebra. Although in the thoracic cavity it may be pressed upon by tumors and aneurysms, and its rupture is reported by Krabbel in a case of fracture of the ninth thoracic vertebra, followed by a chylous effusion of more than a gallon in the right pleural cavity, it is *in the neck* that its *surgical interest* lies. Here it has been *wounded* by stab and bullet wounds and in extensive operations for tumors or tuberculous glands of the neck. The near neighborhood of many vital parts would render rapidly fatal most injuries of the duct, unless received during a surgical operation. Under normal anatomical conditions operative injury is very unlikely, as the duct rises little if any above the level of junction of the two great veins; but it not infrequently rises higher, and has been found as high as 5½ cm. (2¼ in.) above the sternum (Dietrich). When injured it has been successfully sutured in a few cases, and in others its leakage has been checked by clamps or packing.

Obstruction of the duct in man is not followed by constant nor always by marked symptoms, for the lymphatics are continuous with the interstices of the tissues and communicate with other veins, like the azygos veins and small veins in the groin (Leaf), hence a collateral circulation may be established. Chylous ascites or pleural effusion may be due to obstruction with transudation or to wound or rupture of the duct or its larger tributaries.

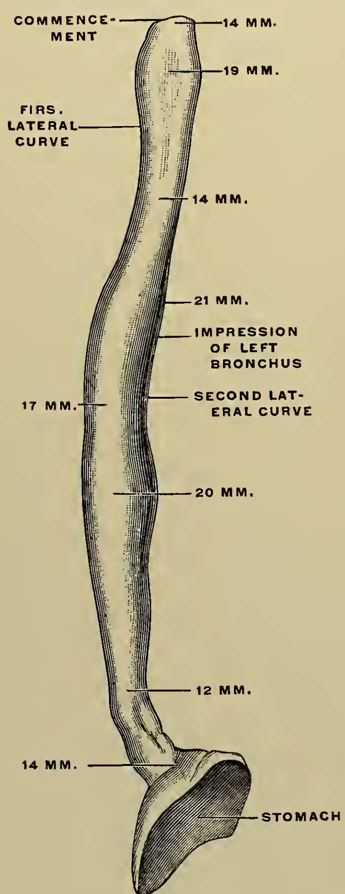
Its *obliteration* has occurred without producing any marked symptoms, though experimental ligation in dogs has been followed by rupture of the receptaculum chyli or other fatal lesions. A double perfect *valve* at its entrance into the veins guards against regurgitation of lymph or the entrance of blood. It may enter the veins as a delta. It *receives the*

lymph and chyle from all parts of the body except the right upper extremity, the right side of the chest, head, and neck, and the convex surface of the liver, which is returned by the **right lymphatic duct** to a corresponding point of the veins on the right side. Its injury is of less moment.

THE ESOPHAGUS.

Like the thoracic duct, the esophagus is contained partly in the neck and abdomen, but mostly in the thoracic cavity, in the superior and posterior mediastina. The *level of the commencement* of the esophagus, as the continuation of the pharynx, depends, like that of the trachea, on the position of the head and neck and varies from the fifth to the sixth or seventh cervical vertebra. In a position midway between flexion and extension of the neck its upper end, behind the lower border of the cricoid cartilage, is *opposite* the *sixth cervical vertebra.* Its *lower end* passes through the diaphragm, opposite the tenth thoracic vertebra, to end in the stomach, opposite the eleventh vertebra. Its **length** averages 23 to 25 cm. ($9\frac{1}{4}$ to 10 in.), which with the distance of its upper end from the upper incisor teeth, 15 cm. (6 in.), makes the average distance from the latter to the stomach 38.5 to 40 cm. ($15\frac{1}{2}$ to 16 in.)—17 cm. in the new-born (Mouton). The length of the cervical portion, *i. e.*, above the episternal notch or the second thoracic intervertebral disk, averages 5 to 7 cm. (2 to $2\frac{3}{4}$ in.) and ranges between 4.5 and 8.5 cm. (Tillaux), varying with the length and position of the neck.

Fig. 94



Plaster cast of esophagus, showing its curves and diameters. (Mouton.)

Its **direction** (Fig. 91) is not straight. It *inclines to the left* in the neck but is pressed back to the median line by the left end of the aortic arch, opposite the fourth thoracic vertebra. Below this it again curves slightly to the left, so that its diaphragmatic orifice is normally somewhat to the left of the median line and to the left and in front of the aorta. In the sagittal plane it follows the curved line of the vertebræ to the fourth

thoracic vertebra, below which it gradually leaves the vertebræ and passes more vertically to its diaphragmatic orifice. None of its curves are of sufficient extent or degree to interfere with the passage of bougies or straight instruments.

The Lumen.—The lumen of the esophagus, except during the act of swallowing or vomiting, is always closed in the cervical portion, sometimes closed and sometimes open in the thoracic portion, according as the stomach is full or empty of gas or fluid. The **caliber** of the esophagus, which is the narrowest section of the alimentary canal, varies and presents **three constricted parts**, one at its commencement, another 7 to 10 cm. (2¾ to 4 in.) below, and the third at its passage through the diaphragm, 22 cm. (9 in.) below. The latter is not a narrowing of the tube itself, but is due to the fibers of the diaphragm which surround it and form a kind of sphincter for it. The *lowest constriction* is the *narrowest*, measuring 12 mm. in *diameter* as compared to 14 mm. for the upper two, but it is *more distensible*, allowing of rapid dilatation to 22 mm., the other two to 18 or 19 mm.

It follows that in an adult's esophagus a **bougie** 14 mm. in diameter should pass easily, otherwise there is a stenosis, and that in *dilating* the esophagus an instrument of 18 mm. diameter should be the limit. In the *newborn* the *caliber* of the esophagus is 4 mm. In passing a bougie, stomach tube, etc., the patient's head is thrown back, to straighten the curve made by the roof of the mouth and the pharynx, the tongue and epiglottis are pressed forward by the finger, and the point of the instrument is guided to the posterior pharyngeal wall, a little to the left, and along it down to the upper end of the esophagus. On account of a *spasmodic muscular contraction* the introduction of a bougie may be hindered at the upper end of the esophagus, and lower down it may be suddenly held in the same way. During the muscular spasm the sound should be left at rest, as the attempt to force it increases the spasm, but the latter will relax if the patient makes the movements of swallowing. Owing to the firm relations in front of and behind the esophagus, *i. e.*, trachea and vertebræ, it is less distensible in these directions than laterally, as seen in sword swallowing. Accordingly some bougies are made flattened.

Any **foreign body** which will pass the upper two narrow points will probably pass the lower one. Foreign bodies are, therefore, most likely to be *arrested* at the upper end of the esophagus, or the lower end of the pharynx, where the predominance of striped muscle tissue in the walls often allows of their being returned to the mouth by a spasmodic muscular action. If this fails, they may be removed by some form of esophagus forceps, as may also those bodies arrested at the *second narrow point*, which begins 3.5 cm. and is narrowest 7 cm. below. If the forceps or coin-catcher fails to remove a body arrested at the second constriction, two alternatives present themselves—pushing it down to the stomach or removing it by an external esophagostomy.

Strictures.—Strictures of the esophagus, both malignant and cicatricial, are most likely to be found at one of the constricted points. The *cica-*

tricial variety occurs most frequently at the narrow points because the corrosive fluid swallowed takes slightly longer in passing these points, and hence acts more intensively on the esophageal wall, causing deeper ulceration and greater subsequent contraction. **Cancerous stricture** is most common at the upper or lower ends, and in the latter case the symptoms are not infrequently referred to the upper end.

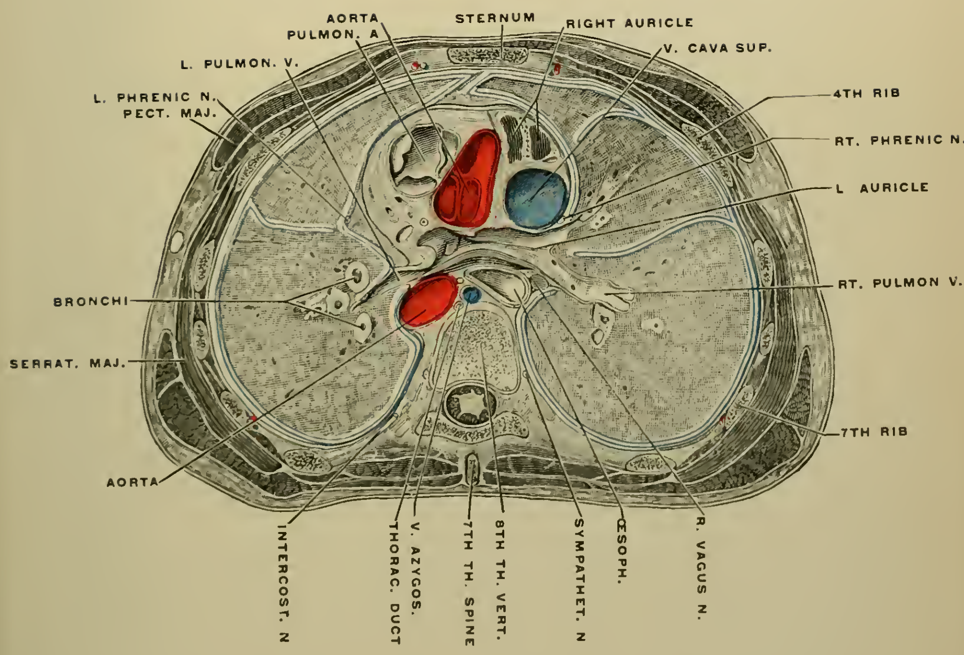
The **lymphatics** enter the mediastinal and the deep cervical lymph nodes so that if cancer of the esophagus is suspected we should examine the nodes of the carotid chain at the root of the neck.

Relations.—The relations of the esophagus are especially important *at the narrow points*, where lesions are likely to occur, *and in the neck*, where esophagotomy is done and where other operations and injuries may concern it. The **second constriction** is just above or behind the aortic arch and the left bronchus, and *foreign bodies* arrested here have *ulcerated* through into the aorta, causing immediate and fatal hemorrhage. Thus, a five-franc coin (Musée Dupuytren), a fishbone (*Lancet*, 1871), etc., have been reported ulcerating into the aorta, and a piece of bone impacted in the esophagus has been reported (Ogle, in *Path. Soc. Trans.*, vol. iv), ulcerating into an intervertebral disk and setting up a fatal disease of the cord. *Aneurysm* of the aortic arch or descending aorta may press upon the esophagus and *simulate stricture* of its lumen. A bougie passed under such conditions may penetrate the sac and bring on a sudden fatal bleeding. Similarly an impacted body or an epithelioma has ulcerated into the lower end of the trachea, the left bronchus or the right pulmonary artery, which also lies in front of the esophagus. An instrument passed in case of a carcinomatous stricture of the esophagus may readily pierce the softened wall of the tube and penetrate the trachea or left bronchus, setting up a septic pneumonia, or it may wound the aorta, pericardium, pleura, etc., with a fatal result. The contiguity of the esophagus with the membranous wall of the trachea and with the left bronchus explains the effect of foreign bodies in the one producing symptoms of obstruction referable to the other, so that tracheotomy has been done for a foreign body in the esophagus. Of course, foreign bodies, especially sharp or irregular ones, may become arrested elsewhere than at the narrowest points.

The *aorta* winds spirally around the esophagus, being in front above, then to the left, then behind, and finally behind and to the right. *Below the aortic arch* the esophagus is just behind the bronchial glands, the pericardium and the left auricle, so that in enlargement of the heart or distention of the pericardium with fluid the patient may be unable to swallow with comfort in the supine position. The esophagus lies between the two *pleural sacs*, but in more direct contact with the left above and the right below. Hence carcinoma of the esophagus is said to extend to the right lung and pleura more often than to the left, though I have observed it on the left side. The *thoracic duct* is to the right below, to the left above, and crosses behind it about the fourth or fifth thoracic vertebra. Loose cellular tissue, continuous with that behind the pharynx, connects the esophagus with the prevertebral fascia, etc., and along this

PLATE XXVII

FIG. 95



Transverse Horizontal Section of the Body at the Level of the Eighth Thoracic Vertebra. (Joessel.)

a retropharyngeal abscess or a deep abscess of the neck may descend into the mediastinum and press upon the esophagus.

In the neck its **relations** are of importance, especially *on the left side*, on which **external esophagotomy** is performed as the esophagus inclines to the left. In this operation the left recurrent laryngeal nerve, the inferior thyroid artery, and the left lobe of the thyroid gland, which lie in front of the left side of the esophagus, must be carefully avoided. After *incising* along the anterior border of the left sternomastoid, from the thyroid cartilage downward, this muscle and the carotid sheath are retracted outward, the other structures inward. The recognition of the esophagus is made easier by a bougie passed into it through the mouth. On the *right side* the carotid sheath is farther removed from the esophagus, and the recurrent laryngeal nerve runs more along its lateral border. The modern operation of gastrostomy gives good results, and is far preferable to esophagostomy. The thoracic portion of the esophagus may be operated on through an opening in the anterior or posterior part of the thorax. The collapse of the lung is prevented by the use of increased (positive) pressure in the lungs or by operating in a compartment in which the pressure is diminished (negative pressure), as in Sauerbruch's chamber. In cicatricial strictures there is a pouch-like dilatation of the esophagus above the stricture, the opening of which is usually eccentric, so as to prevent the passage of bougies from above. Hence the retrograde dilatation through an opening in the stomach is the best method. A thread swallowed will readily pass even the narrow eccentric strictures, and the lower end may be washed out through the opening in the stomach. Foreign bodies impacted at the lower end may be removed by gastrotomy (Richardson).

Congenitally the esophagus may be deficient in part and open into the trachea below or, more rarely, above, or it may also be the seat of a tracheo-esophageal fistula, an annular stricture, a dilatation, or a doubling or division of the tube. The esophagus may be much dilated above any stricture, but especially above the spastic condition known as cardiospasm, in which the tube above the cardia may contain a liter or more. True *diverticula*, both pulsion and traction diverticula, are acquired. The former are due to a hernia of the mucosa through the inferior constrictor of the pharynx on the posterior wall at the upper end of the esophagus or the lower end of the pharynx, the latter are due to the contraction of scar tissue connecting the esophagus with surrounding parts (*i. e.*, bronchial glands, etc.), and are most often on its anterior wall just below the bifurcation of the trachea.

CHAPTER IV.

THE ABDOMEN.

Shape.—In general the abdomen is barrel-shaped, flattened from before backward, bulging in the centre and wider below than above. In the adult *female* the larger circumference below than above is due to the size of the pelvis, largely due to the accumulation of fat, and is still more marked when the upper part has been compressed by corsets. In *childhood*, owing to the incomplete development of the pelvis, the abdomen is larger above than below, especially in its transverse diameter. The **height** of the abdomen in the female is greater than in the male, owing to the greater size of the lumbar vertebræ. The **long axis** of the abdominal cavity is not vertical but oblique from above downward and to the right, owing to the greater height of the diaphragm on the right side. The *intra-abdominal pressure* acting most strongly in this line is said to account for the greater frequency of hernia on the right than on the left side.

In fat subjects the abdomen protrudes to a varying degree in front, owing to the deposit of fat among the abdominal viscera and the peritoneal folds and to the large amount of subcutaneous adipose tissue. In time, the protrusion is carried downward by gravity, aided by the laxity of the walls and the abdomen becomes pendulous.

In infants the abdomen protrudes in front, owing to the relatively large size of the liver and the small size of the pelvis, which crowds the pelvic viscera (bladder, rectum, etc.) partly up into the abdomen. The latter condition, apart from the amount of fat, accounts for the protrusion of the abdomen in children until the pelvis enlarges at the approach of puberty.

Certain physiological and pathological conditions cause a general or local protrusion of the abdomen, such as pregnancy, ascites, distention of the hollow viscera (tympanites), enlargement of the solid viscera, and tumors or cysts of the abdominal contents or walls. After long-continued distention, an undue amount of prominence or pendulousness often remains.

In cases of great *emaciation* from starvation or wasting disease, the contour of the abdomen is much depressed in front and especially just beneath the costal margin where the slight normal median depression, known as the "*pit of the stomach*" (or scrobiculus cordis), may become so marked that, in the recumbent position, the wall sinks away almost vertically from the costal margin and the prominence of the vertebræ is noticeable. In tuberculous meningitis and lead colic the abdomen shows a "boat-shaped" depression in front, owing to the contraction of the empty bowels.

Boundaries.—The abdomen, including the pelvis, is bounded *above* by the diaphragm, which separates it from the thorax, *below* by the pelvic floor. A *plane* drawn through the base of the ensiform cartilage in front and the tenth thoracic spine behind suggests the upper limit of the cavity, which, however, ascends even higher than this into the vault of the diaphragm.

The actual upper limit of the abdomen, extending up as it does under cover of the lower ribs and costal cartilages, is higher than the apparent limit, *i. e.,* the costal margin.

It is *bounded behind* by the lumbar vertebræ, sacrum, lower two or three ribs, diaphragm, lumbar muscles, and the posterior portions of the ilia; *in front,* by the costal cartilages, forming the costal margin, the symphysis, the body and rami of the pubis, and the ventral abdominal muscles; *laterally,* by the lower ribs and diaphragm, the ilia and ischia, and the fleshy portions of the flat abdominal muscles.

Except for operations on subdiaphragmatic and liver abscesses and wounds through the diaphragm, after suture of the diaphragm to the opening in the costal pleura, no operations are done through the upper boundary or diaphragm. Many operations are performed through the perineum and the pelvic floor on the rectum, female pelvic organs, and male genito-urinary organs. Hahn's operation for gastrostomy is done through the eighth intercostal space, and occasionally the iliac fossa has been perforated for drainage of an abscess. Otherwise abdominal operations are performed through the soft parts, which indicate the apparent limit of the abdomen and form an hexagonal area bounded by the costal cartilages of the six lower ribs and by the twelfth ribs above, the transverse processes of the lumbar vertebræ behind, and by the iliac and pubic crests and Poupart's ligaments below.

Superficial Markings and Landmarks.—**Bony Points.**—Superiorly the *ensiform cartilage* and the diverging margins of the *costal cartilages* (bounding the *infracostal angle*) are often visible and always palpable. The tip of the ensiform cartilage is about on a line with the lower part of the tenth thoracic vertebra. There is a palpable *notch on the costal margin* between the tip of the tenth and the border of the ninth costal cartilage, which is a useful landmark.

The tips of the *eleventh and twelfth costal cartilages* lie free between the abdominal muscles. They can be readily felt except in fat subjects, but it is never safe to rely upon palpation alone in determining the twelfth rib (see p. 315), and the ribs should always be counted from above to locate the twelfth rib in lumbar operations.

As the *spines* of the *lumbar vertebræ* closely correspond with the level of their bodies, some of the relations of the latter may here be given according to Holden and Windle:

First lumbar vertebra and spine: pancreas, pelvis of kidney, with endings of renal arteries. Junction of first and second: end of spinal cord. Second: duodenojejunal junction; opening into intestine of ductus communis choledochus, upper end of root of mesentery, commencement of portal vein, superior mesenteric artery, and thoracic duct.

Third: lower border of kidney. Junction of third and fourth: umbilicus. Fourth: highest part of iliac crest, bifurcation of aorta. Second or third sacral vertebra: limit of spinal membranes.

The anterior superior iliac spine is an important landmark in determining the length of the lower extremities in fractures of the femur and in injuries and diseases about the hip-joint. On a line between it and the umbilicus, about 5 to 6 cm. (2 to $2\frac{1}{2}$ in.) from the iliac spine is "*McBurney's point*," commonly the point of greatest tenderness in appendicitis. This spine is at the outer extremity of the *inguinal fold* (due to Poupart's ligament), where in thin subjects it is visible as a prominence, in fat subjects as a depression, and in all subjects it is palpable. It lies at or below the level of the top of the promontory of the sacrum, in the erect position.

Extending outward and upward from this spine the sinuous *iliac crest* may be felt throughout, except mesially, in very fat subjects. In muscular subjects it lies in a groove (*iliac furrow*) below the fleshy fibers of the external oblique muscle. It ends mesially in the *posterior superior iliac spine,* often difficult to feel, but indicated by a slight *depression* on a level with the spinous process of the second sacral vertebra.

The pubic spine is another bony landmark of special importance in the anatomy of hernia, lying external to the neck of an inguinal hernia and internal to that of a femoral. It lies at the inner end of the inguinal furrow and of Poupart's ligament. It is readily palpable except in fat subjects, in whom it may be found by following up the adductor longus tendon and, in the male, by invaginating the scrotum and thus getting beneath the subcutaneous fat. It lies in the same horizontal plane with the upper border of the great trochanter. Between it and the symphysis pubis the *pubic crest* may be felt, except in the obese.

Lines, Muscles, etc.—The **linea alba** (see also p. 275), corresponding to the fibrous interval between the two recti muscles, is marked by a slight median groove (*the abdominal furrow*) from the *infrasternal depression* (pit of the stomach), below the ensiform cartilage, to a little below the umbilicus. Below this it is only visible in those without much subcutaneous fat when the recti muscles contract, owing to their close approximation, and the concealment of their lower ends by a small amount of fat.

The umbilicus (see also p. 257) lies 20 to 25 mm. ($\frac{3}{4}$ to 1 in.) above the bifurcation of the aorta, about on a line connecting the highest points of the iliac crests and on a level with the disk between the third and fourth lumbar vertebræ and the lower end of the third lumbar spine. Whereas, at birth it lies below the centre of the body, in the adult it is above this point, which lies nearer the symphysis pubis. It always lies below the centre of the linea alba, about the junction of its upper three-fifths with the lower two-fifths, and it is displaced downward when the abdomen is obese or pendulous.

The linea semilunaris (see also p. 274) corresponds to the outer border of each rectus muscle, and may be well seen when that muscle is in action, as a slightly curved line convex laterally, from the tip of the ninth

costal cartilage to the pubic spine. This border extends to the midpoint of the line joining the umbilicus and the anterior superior iliac spine, except in a protruding abdomen. It lies, on the average, about 7.5 cm. (3 in.) laterally from the umbilicus, and above that level the line is indicated by a shallow groove which ends above at the margin of the thorax in a somewhat triangular *infracostal fossa.*

When in action the rectus presents three slight transverse grooves extending between the lineæ alba and semilunaris and representing the **lineæ transversæ** (see also p. 272). One is about the level of the tip of the ensiform cartilage, a second at that of the tip of the tenth rib, or midway between the first and the third, which is at the navel. Occasionally a fourth occurs below the navel, in the outer half of the muscle.

The **inguinal furrow** corresponds to Poupart's ligament, and is an important landmark in the surgical anatomy of hernia.

Lateral to the linea semilunaris the upper part of the fleshy portion of the *external oblique* is seen interdigitating with the serratus magnus in a zigzag line directed obliquely downward and backward. Its prominence above the iliac crest forms the iliac furrow which corresponds to the crest.

The **superficial epigastric vein** (see also p. 279) is often visible through the skin, especially if enlarged, when it may be seen to communicate with another vein (thoracico-epigastric) which joins the axillary vein, as well as with the superior epigastric branch of the internal mammary vein.

THE ANTERIOR ABDOMINAL WALL.

The *lateral limits* may be taken to be the lateral border of the external oblique muscle, which alone of the flat abdominal muscles has a free lateral margin between the thorax and the iliac crest (see p. 271). The soft parts may be studied by layers and then certain important areas considered separately.

The Skin.—The skin is thin and loosely attached to the tissues beneath, except around the umbilicus and, to a less extent, in the median line. Below the umbilicus the linea alba is often indicated by a line of pigmentation in the skin. In the male the skin, especially above the pubis and near the median line, is often beset with *hairs.* The numerous hair follicles may make it difficult to make the skin reasonably aseptic. The *cleavage lines* of the skin are in general parallel with the course of the lower intercostal and the upper lumbar nerves. When the skin has been greatly stretched from abdominal distention, scar-like silvery streaks *(striæ gravidarum)* appear, especially in the lower part where the distention is usually greatest. They are due to atrophy of the skin from stretching, but are not evidence of pregnancy, for they may follow any great distention.

The Superficial Fascia.—The superficial fascia, unlike the subcutaneous tissue in most regions, consists of two layers, which are most distinct in the lower half of the abdomen. Between the two layers at the groin are

the superficial bloodvessels. Both layers are continued on to the external genitals and the perineum.

The Superficial Layer.—The superficial layer of the superficial fascia contains the *subcutaneous fat,* the deposit of which is greatest toward the middle and lower part, reaching its maximum in the female over and about the pubis, as the *mons veneris.* The fatty deposit may reach such a *thickness* (15 cm. [6 in.] has been found) as to make examination of the abdominal wall or contents impossible, and even to contra-indicate operation. The thicker the layer, the longer the incision required. The fat of the abdominal wall acts as a non-conductor to prevent changes of temperature affecting the viscera, and thus serves as a "cholera band." The comparative thickness of the belly wall in different subjects depends upon the amount of this fat rather than upon the thickness of the muscles.

This layer is continuous with the superficial fascia on all sides. *In thin subjects* the fat may be so small in amount that not only are the muscles and superficial markings very clearly seen, but intestinal peristalsis ("peristaltic wave") may be felt and seen and visceral tumors may be readily outlined through the thin wall. *In very fat subjects,* two *deep folds,* involving the skin and this layer, run transversely across the abdomen, one at the umbilicus, concealing it, and the other just above the pubis. Where the latter crosses the median line the trocar should be introduced in tapping the bladder. These folds are due to a slight absorption of fat, due to the pressure of the creasing of the skin in bending forward.

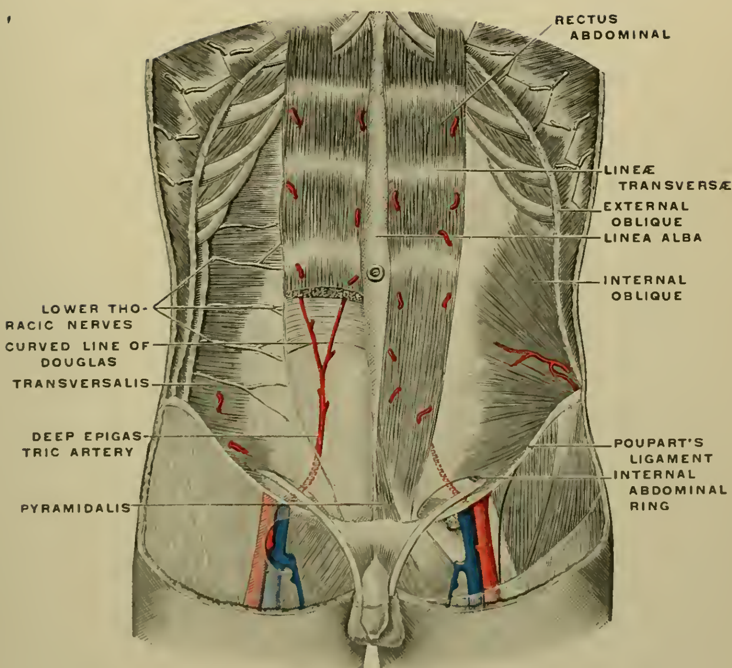
The Deep Layer.—The deep layer of the superficial fascia consists of a firm membrane containing elastic fibers. It is firmly *attached* to the deeper parts in the median line down to the symphysis and to the fascia lata just below Poupart's ligament and along the iliac crest. Between the symphysis and the pubic spines it is not attached to the underlying parts, but, uniting with the superficial layer, which here has lost its fat, it passes down to become continuous with the dartos of the scrotum and penis. Many interesting clinical facts depend upon this arrangement. Subcutaneous emphysema due to injuries of the chest, lipomata, blood or pus beneath this layer are arrested at the median line, the inguinal fold, and the iliac crest, and are prevented from reaching the thigh or the buttock by reason of its firm attachment to deeper parts. They may, however, pass down into the scrotum between the symphysis and the pubic spines. If the same conditions occur superficial to this layer, they may readily extend in all directions.

Tillaux describes a lipoma beneath the deep layer in the inguinal region, which was thought to be an inguinal hernia, but was shown not to be by reason of the emptiness of the inguinal canal.

In like manner extravasated urine, pus or blood in the scrotum may ascend onto the abdomen, between the pubic spines and the symphysis, but cannot cross the median line or descend onto the thighs without first perforating this layer. Between the two layers lie the superficial vessels, hence we may remember, in making incisions, that the fatty layer is free from large bloodvessels.

PLATE XXVIII

FIG. 96



Muscles, Vessels, and Nerves of the Anterior Abdominal Wall.
(Joessel.)

Of little surgical importance, as far as the abdomen is concerned, is a *thin cellular fascia* covering the external oblique muscle. In the inguinal region this seems to be continuous with the *intercolumnar fibers* and to be continued down into the scrotum as the *external spermatic fascia*, one of the coverings of the cord or of an inguinal hernia.

The Muscular Layers.—The muscular layers present vertically directed fibers mesially, in the rectus and pyramidalis muscles, and obliquely directed fibers laterally, in the external and internal oblique and transversalis muscles. The strength of the abdominal walls depends chiefly upon the muscles. It should be remembered, however, that these muscles are much *thinner*, in most cases, than one would be led to suppose from their description in text-books.

The flat *fleshy bellies* of the *oblique muscles* are found largely at the sides, where they fill in the interval between the vertical muscles behind and in front, except for a narrow strip along the outer border of the rectus, where their aponeuroses form the fibrous semilunar line, and a small *semilunar area* beneath the conjoined tendon.

The *fleshy portion* of the **external oblique** terminates in a right angle, readily seen in muscular subjects, some distance from the border of the rectus. It lies above a horizontal line drawn from a point on the iliac crest 2.5 to 5 cm. (1 to 2 in.) behind the anterior superior iliac spine, and external to a vertical line from the lowest point of the ninth rib. It also lies somewhat above a line connecting the anterior superior iliac spine with the umbilicus; hence only the upper part of the usual oblique incisions in this region involves the fleshy fibers of this muscle. It is the only one of the three flat muscles in question which has a *free posterior border*, between its attachment to the last rib and the middle of the iliac crest, the other two muscles being connected posteriorly with the lumbar fascia. This free lateral border may be overlapped throughout by the latissimus dorsi, or a triangular interval of varying size may be left between these two muscles and above the iliac crest, the **triangle of Petit**, whose floor is formed by the internal oblique. This is a point of least resistance where abscesses may point or a rare form of hernia may occur (lumbar hernia).

The *direction* of the muscular and aponeurotic fibers of the external oblique is approximately at right angles to the line connecting the anterior superior iliac spine and the umbilicus.

The *fleshy portion* of the **internal oblique** extends beyond that of the external both mesially and laterally, especially inferiorly and mesially. The *lower fibers*, blended with those of the transversalis to form the *conjoined tendon*, are directed downward and inward and arch over the inguinal canal to be inserted into the inner 2.5 cm. (1 in.) of the iliopectineal line and the pubic spine and crest, in front of the rectus. This passes behind the external abdominal ring and covers and strengthens an otherwise weak area in the inguinal region, but leaves a narrow uncovered space between its lower curved margin and the inner half of Poupart's ligament (see Inguinal Region, p. 290). The fleshy fibers of the internal oblique are *directed* in a fan-shaped manner, but, except

those forming the conjoined tendon, the general direction is upward and inward, crossing those of the external oblique nearly at a right angle, like bars of lattice-work. They do not reach above a horizontal line drawn below the tip of the last rib, nor in front of a line drawn upward and a little outward from the centre of Poupart's ligament, except for the conjoined tendon.

The *fleshy fibers* of the **transversalis**, *directed* for the most part transversely, present mesially a concave margin, approaching nearer the middle line above and below. The *upper fibers* pass beneath the rectus, and therefore underlie the semilunar line in the upper part; the *lower fibers* take part in forming the *conjoined tendon*, but arch higher above the inguinal canal and give no covering to the cord or a hernia, as does the internal oblique by means of the cremaster muscle.

These three flat abdominal muscles are *separated* from one another by a certain amount of loose connective tissue, which favors the spread of inflammation from a wound or of a *mural abscess* from spinal caries, etc. Such abscesses will be limited by the semilunar line in front, the erector spinæ behind, Poupart's ligament and the iliac crest below, and the costal arch above, and usually work down to the iliac crest, the inguinal fold, or along the inguinal canal into the scrotum or labia.

Between the internal oblique and transversalis muscles run the main trunks of the lower *thoracic* and upper *lumbar nerves* that supply the muscles and skin of the abdomen.

The different direction with the resulting *crossing of the fibers* of the oblique and transversalis muscles has the following *practical* results: (1) It strengthens the abdominal wall and greatly reduces the possibility of a hernia between the separated fibers of the muscles. (2) It permits contraction of the abdominal wall in every direction, and thus (3) increases the amount of abdominal pressure for the expulsion of urine, feces, and the fetus. (4) It produces greater approximation in the movements of the movable bony boundaries of the abdomen. (5) It affords a landmark or an index as to the depth of an incision in operations.

Before studying the aponeuroses, or tendons, of the above muscles it is convenient to consider the vertical muscles, the rectus, and pyriformis.

The **two recti** run longitudinally the entire length of the abdominal parietes on either side of the median line. They are much narrower below than above, and in the upper two-thirds are said to be about as broad as the hand, at the heads of the metacarpal bones. The longitudinal fibers are *interrupted by fibrous intersections* at the **lineæ transversæ**, so that they do not run the entire length of the muscle. The lineæ transversæ *represent* the septa which divide the muscles of the abdomen at intervals in the lower vertebrates and the abdominal ribs of the crocodile. The latter analogy is indicated by the relation of some of the lower thoracic nerves to the intersections, similar to that of these nerves to the ribs. The intersections serve the important *function* of holding together the fibers of the muscle and preventing the formation of ventral hernia in cases of great abdominal distention from pregnancy, etc., but they do not offer serious resistance to the longitudinal separation

of the fibers in a vertical incision through the rectus. They prevent the extensive retraction, after division of the muscle, which would result if the fibers were uninterrupted. Resembling as they do transverse scars, they indicate that transverse incisions of this muscle, if healed by a proper cicatrix, only increase the number of such transverse intersections which nature provides to strengthen the muscle, and therefore can do no harm. These fibrous intersections are *adherent* to the front but not to the back of the sheath of the rectus; hence *suppuration* in the rectus may be *limited* to the interval between two transverse intersections, or below the lower one, though it may extend along its entire dorsal surface where the intersections are not connected with the sheath.

By means of this connection of the intersections with the sheath, the action of the rectus may affect the latter and the aponeuroses of which it is formed, thus diffusing its action. They allow part of the muscle to act at a time, as, for example, the lower part in micturition.

Similarly the rectus may be the seat of a form of **phantom tumor** in hysterical subjects, due to the contraction of a part of the muscle, usually to a segment between two intersections. The irregular contraction of other abdominal muscles may also cause a phantom tumor. When associated with distention of the bowels from flatus or feces, and with abdominal or pelvic symptoms, such tumors may mislead. The relaxation of the contraction from an anesthetic, or otherwise, causes the tumor to disappear. They are said to be more common in the left rectus. The position of the intersections has already been given (see p. 269).

The fibers of the rectus are in rare instances *torn* by muscular violence and in opisthotonos.

Below the umbilicus the two *recti* are so *close* together that it is scarcely possible to make a median incision without exposing the mesial fibers of one or both.

The pyramidalis muscles *lie* beneath the sheath of the recti, in front of the latter muscles and separated from them by a layer of fibrous tissue. They are inserted into the linea alba one-third to one-half the distance between the symphysis and the umbilicus, and, when large, may entirely cover the median line, so that division of their fleshy fibers cannot be avoided in a median incision. They may be absent or unusually small on one or both sides.

The anterior aponeuroses of the oblique and transversalis muscles *extend* from the mesial borders of the fleshy portion of these muscles to the median line, where they *unite* with those of the opposite side to form the *linea alba*. Thus the transversalis muscles of the two sides may be considered a double-bellied muscle with an intervening tendon, and the same may be said of the external oblique on one side with the internal oblique of the opposite side, for their fibers run in a similar direction. The aponeurosis of the external oblique is widest below, that of the internal oblique above, and that of the transversalis in the middle.

The Inguinal or Poupart's ligament is *formed* of the thickened lower fibers of the aponeurosis of the external oblique which *extend* from the anterior superior iliac spine to the pubic spine. It can be felt as a firm band.

Beneath it the iliopsoas muscle, the femoral vessels, the anterior crural, the external cutaneous, and the crural branch of the genitocrural nerves pass from the pelvis into the thigh. It is somewhat *infolded* on itself so as to form a kind of gutter, the concavity of which is directed upward and inward, and the dorsal margin of which is loosely connected with the transversalis fascia and, in the outer part, with the iliac fascia also (Fig. 97). Upon the concavity of this gutter lie the structures which pass out at the external abdominal ring.

Inferiorly it is firmly connected with the fascia lata of the thigh, which, in the extended position of the hip, pulls it downward so as to make it *convex downward.* Hence, in **palpation of the abdomen,** as well as in the reduction of a hernia, the thighs are flexed on the pelvis, which relaxes the traction of the fascia lata on Poupart's ligament and the muscles and aponeuroses connected with it, and thus relaxes the abdominal walls. In addition, the stomach, bowels, and bladder should be empty to facilitate palpation.

Poupart's ligament *corresponds* to the *inguinal fold,* and is an important *landmark* in the surgical anatomy of hernia, as well as in the operations performed in the iliac region of the abdominal parietes. Some of its fibers pass nearly horizontally backward to be attached to the inner 2.5 cm. (1 in.) or so of the iliopubic line. These form *Gimbernat's ligament,* whose free, concave, external margin is at the inner border of the crural canal (see p. 304). The latter ligament forms part of the septum between the pelvis and the thigh.

Internal to the pubic spine the fibers of the external oblique aponeurosis are attached to the crest of the pubis. But some of its fibers, known as the **triangular fascia,** cross the median line, decussating with fibers of the aponeurosis of the opposite side, pass behind and strengthen the internal pillar and the inner end of the opposite external abdominal ring, and are attached to the pubic crest and the iliopectineal line of that side, in connection with Poupart's and Gimbernat's ligament and in front of the conjoined tendon.

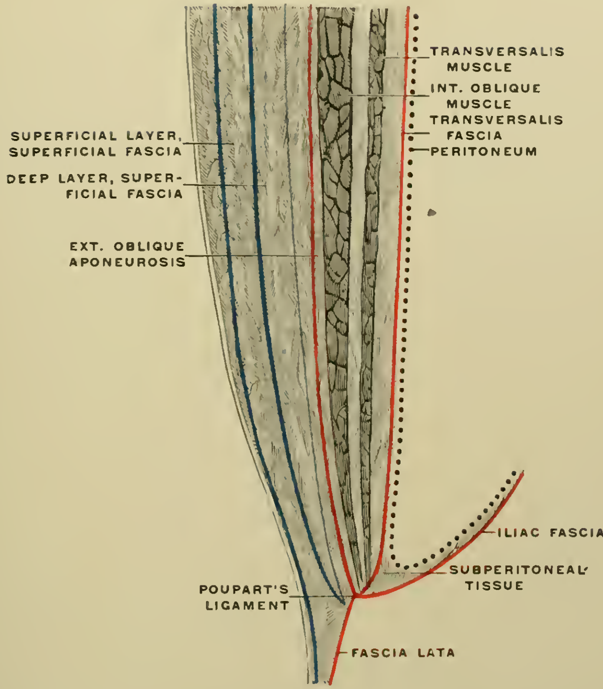
The semilunar line (see also p. 268) indicates the line along which the abdominal aponeuroses divide to form the sheath of the rectus. Along this line, lying between the rectus and the fleshy portion of the lateral muscles, the abdominal wall is composed only of the fibrous tissue of the abdominal aponeuroses, except above where fleshy fibers of the transversalis pass behind it. It is *devoid of large vessels,* except inferiorly where the deep epigastric vessels cross it, hence it is sometimes chosen for incision or paracentesis.

It is concave mesially, corresponding to the outer border of the rectus. The upper end of the line is at or slightly internal to the point where the gall-bladder comes in contact with the abdominal wall. Above a level 3.5 cm. ($1\frac{1}{2}$ in.) below the umbilicus, the semilunar line nearly corresponds to a vertical line erected from the middle of Poupart's ligament.

The sheath of the rectus (Fig. 98) is *formed by* the aponeuroses of the three lateral muscles. The aponeurosis of the internal oblique splits along the semilunar line to pass partly in front with that of external

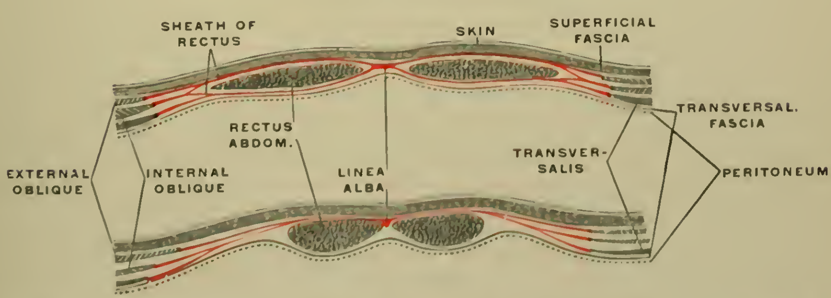
PLATE XXIX

FIG. 97



Sagittal Section of Anterior Abdominal Wall through the Outer Half of Poupart's Ligament. (Tillaux.)

FIG. 98



Diagrammatic Transverse Section of Anterior Abdominal Wall. (Joessel.)

Upper figure above, lower figure below the semilunar fold of Douglas.

oblique and partly behind the muscle with that of the transversalis. This arrangement holds in the upper three-fourths of the muscle, but in the lower fourth, a little above midway between the umbilicus and the symphysis, all three aponeuroses pass in front. The lower border of the dorsal part of the sheath formed by the aponeuroses is concave downward, and known as the **semilunar fold of Douglas**. Below this a delicate fascia, continuous with the fold of Douglas, passes down behind the rectus to the bladder (*fascia Retzii*), in addition to the *transversalis fascia*, which is here firm and thickened and takes the place of the dorsal layer of the sheath.

At the fold of Douglas the *deep epigastric vessels* pass within the rectus sheath in their upward course. From the *extremities* of the folds of Douglas thickened bands or pillars descend, the inner pillar to the symphysis, the outer, or "ligament of Hesselbach" (Braune), splits to enclose the internal abdominal ring, being attached internally to the horizontal ramus of the pubis (and to the pectineal fascia), and externally to the iliac fascia (over the psoas) and to the transversalis muscle where it arises from Poupart's ligament.

The aponeurotic layers which form the ventral and dorsal layers of the sheaths of the recti uniting along their median borders to complete the sheaths join one another to form a *median fibrous raphe*, the **linea alba** (see also p. 268). From the ensiform cartilage to and a little below the umbilicus it is wide, apparent, and easily found, measuring about 6 mm. ($\frac{1}{4}$ in.) in *width* below the ensiform cartilage and 16 mm. ($\frac{2}{3}$ in.) near the umbilicus. Below the umbilicus it rapidly narrows, and thence down to the symphysis the sheaths of the two recti coalesce and it is merely the narrow fibrous interval between them. This fibrous interval may be difficult to find, and in fact it may be said that there is practically no linea alba below the umbilicus, and that it is rarely possible to incise here without exposing the margins of one or both recti muscles, so that the knife need only follow the median line and disregard the linea alba. Just above the symphysis the linea alba expands into a narrow triangular band, *the adminiculum*, only visible on the dosral surface of the abdominal wall. The interval between the two muscles is slightly more marked just above the symphysis in front also, so that it has been suggested to incise from below upward in this part of the linea alba, for the reason that it may be more easily found.

In pregnancy or in abdominal distention from other causes the linea alba becomes much wider, owing to the separation of the recti, reaching 9 cm. ($3\frac{3}{5}$ in.) at the umbilicus and 3 cm. ($1\frac{1}{5}$ in.) at the narrowest part (Cruveilhier). In an otherwise healthy child I have also observed such a congenital diastasis of the recti, with a corresponding widening of the linea alba and a slight umbilical hernia, that the fingers could readily be thrust between the recti, below the umbilicus. A similar condition may exist in "pot-bellied," rickety children. In such cases a ventral hernia may occasionally occur between the two recti muscles. Ventral hernia of the linea alba, when not postoperative, is usually due to the enlargement of small openings which exist normally, some of them for the

passage of small nerves and vessels. Such a hernia should not be confounded with small lipomata which may grow from the subperitoneal tissue through these openings.

The fibrous tissue composing the linea alba is thin and compact, and cannot, as a rule, be separated into layers corresponding to the three aponeuroses which unite from either side to form it. As there are no vessels of any size in the linea alba, it is often selected for incision or paracentesis.

Contraction of the muscles of the abdominal wall make the latter as hard as a board. In this condition they *protect the viscera* within from sudden movement or pressure in acute peritonitis, or from a blow. If a *blow* is expected the instinctively contracted and rigid abdominal muscles protect the viscera from injury like a firm but elastic rubber plate, though they themselves may be bruised or even torn. On the contrary, an unexpected blow upon a flaccid abdomen may seriously wound a viscus without visibly affecting the belly wall, the latter escaping injury by being very freely movable over the viscera. It is impossible to tell the severity of the blow or the seriousness of the injury from outward inspection. In such cases a thick padding of fat in the belly wall or omentum helps to protect the viscera from injury.

On account of the *tonic contraction* of the abdominal muscles a positive pressure (*intra-abdominal pressure*) normally exists in the abdomen. This pressure is increased by the descent of the diaphragm in inspiration, and by straining, lifting, coughing, etc., which favor the production of a hernia and the protrusion of the abdominal viscera through a penetrating wound of the belly wall. Diminution of this pressure and weakness of the muscles which cause it are important elements in constipation, difficult labor, pelvic and abdominal displacements in women, etc.

The transversalis fascia, not to be confounded with the transversalis aponeurosis, lines the deep surface of the transversalis muscles and their anterior aponeuroses, and is *continuous with* the fascia lining the other parts of the abdominal walls.

It is very thin *above* the umbilical level, where it passes up to become continuous with a delicate fascia on the under surface of the diaphragm and *laterally* it is continuous with the anterior layer of the lumbar fascia. *Below the umbilicus* it becomes thicker and firmer as we trace it downward, and here it is important in strengthening the abdominal wall where the tendency to hernia is greatest. This is especially so mesially, where it supplies the place of the posterior sheath of the rectus below the semilunar fold of Douglas, and laterally between the inner half of Poupart's ligament and the conjoined tendon, where it is very strong and strengthens an otherwise weak spot.

It is *attached to* the inner lip of the iliac crest and to the outer half of Poupart's ligament, blending with the iliac fascia. Beneath the inner half of Poupart's ligament, to which it is but loosely attached, it is thickened by transverse fibers to form the *deep femoral arch,* and is continued down into the thigh to form the front of the *femoral sheath.* More

internally it is attached to the iliopectineal line, behind the conjoined tendon, and to the pubic crest, where it is continuous with the pelvic fascia.

In the male, a pouch of this fascia shaped like a funnel, hence called the **infundibuliform fascia**, descends in fetal life with the peritoneal processus vaginalis along the inguinal canal into the scrotum, forming one of the coverings of the spermatic cord and the testis. After the descent of the testis this pouch contracts, so that it closely surrounds the cord in its passage through the inguinal canal, leaving a slight depression with a crescentic mesial border at the internal ring, where the fascia is called infundibuliform. As the transversalis fascia lines the anterolateral abdominal walls, no hernia can occur here without receiving a covering from it.

In *incisions* this fascia may possibly be mistaken for the peritoneum, and the subperitoneal fat beneath it for the underlying omentum.

This fascia will *direct* the course of *an abscess*, etc., lying superficial to it. Such an abscess would be disposed to spread downward, where it would be checked by and point above the attachment of the fascia to the iliac crest and the outer half of Poupart's ligament, or more internally it might run along the inguinal canal into the scrotum.

The subperitoneal (or extraperitoneal) **connective tissue** is a delicate layer of loose connective tissue containing a varying amount of *fat*, which separates the parietal peritoneum from the fascia lining the abdominal walls.

Along the linea alba and at the umbilicus it binds the transversalis fascia and peritoneum closely together. Elsewhere it is more loose and abundant, and *its looseness* favors the spread of abscess, etc., on the one hand, and on the other hand allows the peritoneum to be stripped up from the fascia in extraperitoneal operations on the iliac vessels, ureter, etc.

Owing to the ease with which this tissue allows the peritoneum to be stripped up, care is required to avoid this in abdominal incisions, especially where the peritoneum is adherent to the parts beneath or is thought to be, but has not been incised. Thus in some ovarian cysts the peritoneum has been mistaken for the cyst wall and widely stripped up. The presence of this tissue, especially when thick or containing *fat*, is useful as a *landmark* in abdominal incisions to indicate that the peritoneum has been reached. It should be borne in mind that, in some cases and localities, the amount of fat may be considerable so as not to mistake it for the omentum, as sometimes happens. The amount of fat is greatest in the inguinal, iliac, and lumbar regions, in the latter furnishing the perinephritic fat.

It serves to *connect* those viscera having an incomplete or imperfect peritoneal covering *with the abdominal parietes*, and in such places supports a delicate anastomosis between the parietal and visceral vessels, as in the liver, kidneys, pancreas, duodenum, vertical parts of the colon, rectum, bladder, etc.

Infection may extend from these organs or from an external wound into this tissue, where it readily spreads, usually in the direction of gravity.

Thus an abscess from a neglected appendicitis may extend in the subperitoneal tissue of the iliac fossa to Poupart's ligament, where it may dissect off and displace upward the parietal peritoneum and form a large abscess that can be opened without opening the peritoneum, as was done before the modern operation for appendicitis (Fig. 107).

The *looseness* of this tissue allows the upward displacement of the parietal peritoneum just above the symphysis, when a distended bladder rises out of the pelvis, and thus permits the extraperitoneal tapping or opening of the bladder anteriorly. In front of the bladder it is rich in fat, and forms the loose tissue of the "Cavum Retzii." At the upper end of the crural canal it forms the *septum crurale*, and it descends along the inguinal canal to form a delicate covering of the cord, the testis, or a hernia. Its adipose tissue is the starting point of *subserous lipomata*, which may push through small openings of the overlying parts, as in the linea alba, and simulate an irreducible hernia.

At the internal abdominal ring, especially on its inner side, this tissue contains a considerable amount of fat which, if it be absorbed or diminished from any cause, may leave a depression which favors the formation of a hernia. Its looseness favors the formation of the hernial sac.

A rare form of *properitoneal hernia* may occur in this tissue, *i. e.*, between the peritoneum and the transversalis fascia. The subperitoneal connective tissue forms a *perivascular sheath* for the large vessels which lie in it, and accompanies them outside the abdomen.

The *Parietal Peritoneum* is described later (see p. 317).

Vessels and Nerves of the Anterior Abdominal Wall.—Arteries.— The *superficial arteries* (superficial epigastric and circumflex iliac) are branches of the femoral and lie between the layers of the superficial fascia. They are of little importance, although Verneuil has reported a case of bleeding from the superficial epigastric resulting fatally.

Of the deep arteries, the **deep epigastric**, a branch of the external iliac, is the most important. Where it reaches the anterior abdominal wall, just above Poupart's ligament, it *lies* behind the inguinal canal, just internal to the internal abdominal ring and a little above and to the outer side of the femoral ring. The vas deferens in the male, and the round ligament in the female, loop over it just internal to the internal ring and draw it slightly inward. Its *direction* may be marked off by a line, slightly curved inward, from the outer end of the inner third of Poupart's ligament to a point 2.5 cm. (1 in.) or so external to the umbilicus, crossing the lateral edge of the rectus one-third of the distance between the pubic crest and the level of the navel. In this line paracentesis should not be performed, for hemorrhage from this artery might be free in the loose tissue in which it lies, inferiorly.

In its course it lies at first lateral to the rectus and then behind it. At first it is embedded in the subperitoneal connective tissue, then it pierces the transversalis fascia, and passing within the sheath of the rectus at the fold of Douglas it lies behind the fleshy fibers of the rectus, midway between its borders, and finally within the muscle, where it anastomoses with the *superior epigastric branch* of the internal mammary artery.

Besides the latter artery, small branches derived from the two lower intercostals, the lumbar and the circumflex iliac arteries are found in the abdominal parietes. No artery of the anterolateral abdominal parietes is of such size or importance as alone to contra-indicate a given incision, but it is well to bear in mind the course of the deep epigastric artery and that it crosses the semilunar line.

Veins.—The *deep set* of veins are the paired *venæ comites,* accompanying the deep arteries, in like manner with which they anastomose with one another as well as with the plexus in the subperitoneal tissue and a *parumbilical vein,* which, passing along the round ligament of the liver to that organ, connects the portal veins with the deep epigastric.

The subcutaneous or *superficial set* are single and do not exactly follow the corresponding arteries. The **superficial epigastric vein** is often seen through the skin. It *anastomoses with* the deep and the superior epigastric veins and thereby with the parumbilical and portal veins, and also with a subcutaneous vein (*v. thoracico-epigastrica*) which runs up the side of the thorax to join the axillary vein. This thoracico-epigastric vein may be continued independently into the femoral instead of or as well as joining the superficial epigastric.

The surface veins may become enormously dilated or *varicose,* to the size of the little finger, and so become very distinct. This condition (caput medusæ) usually depends upon their affording a *collateral circulation in obstruction* of the inferior cava or the portal veins, although this varicosity may exist without any such obstruction, and, vice versa, the obstruction may exist without any varicosity. Fig. 120 shows the mechanism of this and other varicosities in portal congestion.

Although it has been shown from the arrangement of the valves that the *current* in these surface vessels above the navel is toward the axilla, and in those below, toward the groin, yet when the veins are dilated the valves become insufficient and the current can take an abnormal course. In portal obstruction the current in the superficial epigastric is toward the groin, where it empties into the femoral or the internal saphenous, and in caval obstruction the current is in the reverse direction and passes into the axillary or innominate through the thoracico-epigastric or superior epigastric veins.

The direction of the current is determined by emptying the veins and allowing them to fill, and is a point that may be utilized in diagnosis.

Lymphatics.—As to the **superficial lymphatics,** those above a level somewhat above the umbilicus go, with those of the breast, to the axillary nodes; those below this level, to the inguinal nodes.

The *deep lymphatics* accompany the parietal vessels to the iliac and sternal glands.

Nerves.—The nerves supplying the anterolateral abdominal wall are the lower seven thoracic nerves, and the iliohypogastric and ilio-inguinal branches of the first lumbar nerve. The *sensory supply* of the skin is furnished by the anterior divisions of the lateral cutaneous branches and the anterior cutaneous branches of the lower seven thoracic nerves and by the hypogastric branch of the iliohypogastric nerve.

The sixth and seventh nerves supply the skin over the "pit of the stomach," the eighth nerve corresponds to the middle linea transversa, the tenth to the umbilicus, the distribution of the twelfth (or subcostal) extends to within 5 cm. (2 in.) of the symphysis, that of the iliohypogastric is below this.

The *muscles* of this region of the abdominal parietes are *supplied by* branches from the same nerves, with the exception of the sixth thoracic and the addition of a few filaments from the ilio-inguinal nerve.

The *anterior portions* of these nerves *pass* between the transversalis and internal oblique muscles to the outer border of the sheath of the rectus, which they pierce to supply the muscle, within which they give off the anterior cutaneous branches. The fact that these numerous nerves supply the abdominal muscles, makes their position and direction of importance in planning incisions.

These nerves are placed at fairly *equal distances* apart, and *pass* downward and inward *in the lower third* of the ventral abdominal wall (*i. e.*, the eleventh and twelfth thoracic, the iliohypogastric, and the ilio-inguinal nerves), nearly transversely inward *in the middle third* (*i. e.*, ninth and tenth thoracic nerves), and somewhat upward and inward *in the upper third* (*i. e.*, the seventh and eighth thoracic nerves).

According to Brewer the course of the *twelfth thoracic nerve* is indicated by a line from a point 12 mm. ($\frac{1}{2}$ in.) below the tip of the twelfth rib to the spine of the pubis on the opposite side; that of the *eleventh thoracic nerve* by a line from a point 12 mm. ($\frac{1}{2}$ in.) below the tip of the eleventh rib to the middle of Poupart's ligament on the opposite side; that of the *tenth thoracic* nerve from a point 12 mm. ($\frac{1}{2}$ in.) above the tip of the eleventh rib to the anterior superior iliac spine of the opposite side. The line indicating the course of the *ninth nerve* is from a point just below the osteochondral junction of the ninth rib horizontally inward, that of the *eighth thoracic nerve* is from a point just below the outer end of the eighth cartilage horizontally inward to a point 12 mm. ($\frac{1}{2}$ in.) to the median side of the chondral border and then upward and inward parallel with the border and 12 mm. ($\frac{1}{2}$ in.) internal to it. In great abdominal distention or obesity these lines would not hold.

The lower nerves run somewhat more transversely than the fibers of the external oblique and its aponeurosis, so that they are in some danger of injury even by *oblique incisions* parallel to these fibers, as in operations for appendicitis, but they may be spared with a little care. *Vertical incisions* of any length, save in or near the median line, cannot avoid exposure and division of one or more of these nerves. Division of these nerves results in paresis of that part of the abdominal muscles which is supplied by the nerves divided, and this paresis causes a weakness and bulging of the abdominal walls and increases the tendency to hernia. The direction of the nerves is nearly, if not quite, parallel to the cleavage lines of the skin.

An inflammation (*perineuritis*) of one or more of these nerves causes *pain* in the area of distribution, and may be accompanied or followed by a vesicular cutaneous eruption limited to the same area and known

as *herpes zoster* (ζωστήρ, a girdle), or shingles. Pain or modified sensation (a sense of constriction or tightness) in the area of distribution may also be caused by pressure on these nerve trunks from injury, tumors, or tuberculosis of the spine or spinal cord. Thus many cases have been recorded where a commencing Pott's disease has been mistaken or treated for "bellyache," or for trouble in the kidneys or bladder when the lower nerves are involved. The position of the spinal segment affected by disease or injury may be localized by the sensory area or the muscles involved.

The *lower thoracic nerves,* besides furnishing the motor and sensory nerve supply to the abdomen, also supply the intercostal muscles and the costal pleuræ. This accounts for the fact that the pain of a pleurisy, especially when near the base of the lung, is often referred to the abdomen, particularly by children who seem to have less ability to locate pain than adults. The abdominal muscles are concerned with the intercostal muscles in the movements of respiration. The association of the sensory nerves of the abdomen with the motor nerves of the inspiratory muscles is illustrated by the violent inspiration or deep gasp given when cold water is thrown upon the belly. The lower ribs are fixed by the reflex contraction of the abdominal muscles so that this inspiration is confined to the upper ribs.

On account of the association in the same nerve of the sensory and motor fibers, the reflex contraction of the abdominal muscles occurs more rapidly than if these fibers were in separate nerves. The *sensory nerves* are thus enabled to do the duty of a *sentinel,* to give warning that can be immediately acted upon by the motor nerves by contracting the muscles. This is an important provision, for, as we have already seen, the viscera are well protected from contusions only when the muscles are first contracted. The rapidity of the reflex contraction is well seen when a cold hand is laid upon the abdomen. Rigidity of the abdominal muscles is immediately caused, so that satisfactory abdominal palpation cannot be practised unless the hands be warm.

A surface lesion like a burn, when rendered painful by exposure to the air, causes the abdominal walls to become rigid. Not only painful surface lesions, but also painful visceral or deep lesions, like visceral injuries and peritonitis, cause by reflex action a tonic rigidity of the muscles or a muscular spasm on pressure, so as to afford complete rest to the inflamed surfaces. This is one of the most important diagnostic signs of a local or general peritonitis. The patient with peritonitis may also be unable to tolerate the least pressure, even of the bedclothes, such is the reflex sensitiveness of the skin.

The explanation of this reflex lies in the fact that the lower seven thoracic and the first lumbar spinal segments, whose spinal nerves supply the abdominal parietes, also supply the abdominal viscera through the corresponding sympathetic ganglia and the splanchnic nerves derived from them. The latter nerves enter the solar and other associated plexuses which provide the nerve supply of the abdominal viscera. The "referred pains" of visceral disease are due to the irritation

of segments of the cord by the sympathetic filaments of the affected viscera. This irritation produces sensory impulses which are referred by the brain to the surface distribution of the segments involved (from which sensory impulses usually come), and not to their point of origin.

Reference to Fig. 199 shows the areas of cutaneous distribution to the abdominal wall of the sixth thoracic to the second lumbar spinal segments. These areas may be sensitive to the touch or the seat of referred pains in lesions of the viscera whose nerve supply is connected with the same segments. Thus, according to Head, the stomach is associated with the 6 to 10 (incl.) thoracic segments, the intestines with the 9 to 12 (incl.) thoracic segments, the liver and gall-bladder with the 7 to 10 (incl.) thoracic segments, the kidney and ureter with the tenth, eleventh, and twelfth thoracic and first lumbar segments.

Congenital Defects of the Abdomen.—During *fetal life* the lateral abdominal walls, as they grow, bend inward to meet and unite in the median line, which they do last of all at the umbilicus. In so-called *extroversion* (or exstrophy) *of the bladder* this median union has failed in the lower part, where the base and posterior wall of the bladder, whose front wall is wanting, is thrust forward by the viscera beneath, so as to appear at or in front of the level of the skin as a red area of mucous membrane, moistened by urine trickling from the visible opening of the ureters. This condition is usually associated with absence of the symphysis pubis and with epispadias.

Again, a failure of the parietes to unite mesially may result in a protrusion of the viscera, especially near the umbilicus, varying in size from a small *hernia* to one involving all the movable viscera.

Injuries and Wounds of the Abdominal Wall.—In *contusions* the fact should be remembered that *ecchymosis* may not occur even though the contusion be severe, and that when the muscles are contracted the viscera are likely to escape injury. A blow on the abdomen should never be considered trivial and refused treatment until after sufficient time has elapsed without symptoms to exclude the possibility of visceral injury. A *blow on the epigastrium* may be followed by *sudden death* without causing marks of parietal or visceral injury. The fatal result is probably due to an inhibitory action on the heart from a concussion of the solar plexus.

The important distinction in wounds of the abdomen is between *penetrating* and *non-penetrating wounds.* In the former the peritoneum is wounded and their seriousness depends upon *infection,* either from without or from a visceral wound, and upon *hemorrhage.* The subjacent viscera may escape injury because the weapon does not reach them or, in rare instances, the intestines have escaped injury from a bullet or a weapon thrust among them.

If *infection* of an abdominal wound occurs, the loose connective tissue between the several layers and the space between the rectus and the rear wall of its sheath favor the spread of inflammation and of pus. The number of layers and the loose tissue between many of them makes it

very easy, in probing a bullet or stab wound, for the probe to leave the track of the wound and pass between the layers of muscles or fasciæ. Hence, probing such wounds is unsatisfactory and is to be condemned.

On account of the different direction of the fibers of the several muscle layers their retraction in a wound or incision is in different directions, so that an irregular wound results. The contraction of the muscles may favor the protrusion of the viscera through such a wound, and, in replacing them, care should be taken not to push them into the spaces between the muscles or beneath the peritoneum. It is important and sometimes difficult to apply the sutures so that the cut edges of each of the muscular layers are in apposition, and unless this is done the strength of the wall is impaired. It is also of the utmost importance that the peritoneum on the two sides of the wound should be sutured so as to bring about its speedy union, otherwise a gap is left on its surface, which favors the formation of a hernia at the site of the wound. The constant movement of the abdominal wall does not allow that rest which is so favorable or even essential to wound healing, but in spite of this most wounds heal well here.

Operations and Incisions.—Operations are practised upon all the abdominal viscera, and for exploration or diagnosis. The *position of the incision* varies with the viscus to be approached. The *general rule* that the incision should give free access and avoid wounding nerves and large or important vessels is to be followed, but in addition the *danger of subsequent hernia* is to be considered. This danger is greater in the lower part of the abdomen, for here gravity adds to the protruding force of the intra-abdominal pressure, due to muscular action. Also, as Hyrtl says, aponeurosis is less resistant than muscle and a scar in the former is more likely to yield than one in the latter.

Incisions (Fig. 99).—Incisions may be *directed* vertically, or obliquely. *Vertical incisions* are most commonly practised along the two fibrous or aponeurotic lines, the linea alba and the *linea semilunaris*. Through the latter line we may *expose* the appendix vermiformis, the kidney, the colon, the gall-bladder, and the bile ducts; but the incision is objectionable because it divides nerves that supply a part of the rectus muscle, and the scar is in relatively thin fibrous tissue and is liable to yield and be followed by hernia.

Of course, in some cases, other considerations (greater safety, etc.) may outweigh the objections. The *danger of hernia* may be lessened by incising the sheath of the rectus muscle 1 to 2.5 cm. ($\frac{1}{2}$ to 1 in.) internal to its outer border, retracting the muscle inward and dividing the deep layer of the sheath in line with the incision of the superficial layer, thus forming a *trap-door incision*. In the upper part of the linea semilunaris the incision is not through fibrous tissue only, but we meet with the transverse fibers of the transversalis muscle, which here passes behind the rectus.

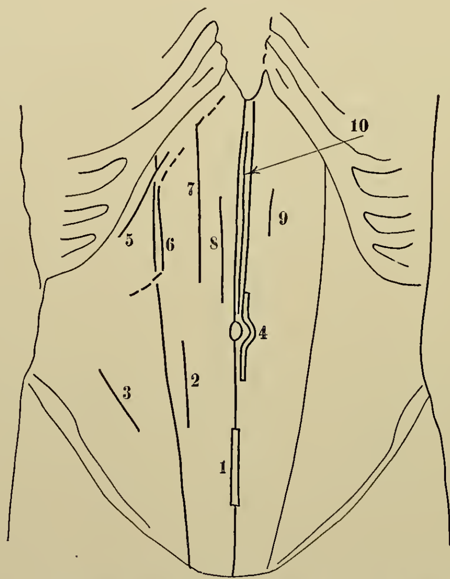
Of all *incisions*, that in or near the *linea alba* is the most common. It is practised in most operations on the pelvic viscera, in most exploratory operations, and in many others. The following *advantages* are

claimed for incisions through the linea alba: (1) *slight vascularity;* (2) *few* important *structures* to be *divided;* (3) *accessibility* to all parts.

1. The *slight vascularity* is a *disadvantage,* for it delays rapid and firm healing and so predisposes to hernia.

2. *Hernia* is also *favored by* the comparatively thin scar resulting from the few blended structures divided and sutured. The incision is also more difficult to make, as it is hard to tell its exact depth at any given stage for want of landmarks. Moreover, if we have to extend the median incision past the umbilicus we encircle it, usually on the left, because of the danger of wounding the parumbilical vein, sometimes of large size,

Fig. 99



Abdominal incisions: 1, median incision in linea alba; 2, Kammerer incision (appendicitis); 3, McBurney incision (appendicitis); 4, median incision encircling umbilicus to left to avoid parumbilical vein and round ligament; 5, oblique incision parallel to right costal margin (gall-bladder), Kocher's incision is parallel and a little lower; 6, Bevan's incision (gall-bladder); 7, Mayo Robson's incision (gall-bladder); 8, posterior gastro-enterostomy; 9, gastrostomy (Witzel, Kader, Senn); 10, median incision, gastrectomy (partial).

which passes along the round ligament of the liver to the right of the median line. But as it is difficult to render the umbilicus aseptic there is danger of infecting the incision or the track of the sutures which unite this part of the incision. The above disadvantages of incisions in the linea alba are avoided and the advantages shared by an *incision through the rectus muscle* about 2 cm. ($\frac{4}{5}$ in.) from the median line, separating bluntly the fibers of the muscle or retracting it outward in the manner of a trap-door. The muscle and its sheath are then sutured separately. The lineæ transversæ offer no serious obstacle to the vertical separation of the fibers of the rectus muscle (see also p. 272).

In the epigastrium the *stomach* is *well exposed* by a vertical incision,

which may be median or through the inner half of the rectus muscle. Occasionally an oblique incision along the costal margin external to the rectus is employed.

Transverse or somewhat oblique incisions in the rectus above the umbilicus are *not objectionable*, if properly united, for they only increase the number of lineæ transversæ and are not likely to wound the nerves. But they are more difficult to suture, so that the vertical incisions are here preferred. Below the umbilicus we should bear in mind the position of the deep epigastric artery in transverse section of the rectus.

The *transverse incision* just *above the pubes to expose the bladder* appears to offer little or no advantage over the vertical, and, unless properly healed, it is likely to impair the function of the muscle as well as to lead to ventral hernia.

In the area outside of the lineæ semilunares the best incisions are those directed obliquely, parallel, or nearly parallel, with the cleavage lines of the skin and the direction of the nerves. Here the incisions are through a thin muscular wall which, if properly united, affords more protection against hernia than those through thinner aponeurotic structures.

In the *lower half of this area* we commonly incise parallel to the fibers of the external oblique and its aponeurosis, *i. e.*, at right angles to a line joining the anterior superior iliac spine and the umbilicus. Separating the external oblique fibers, we may reach the transversalis fascia by blunt separation of the internal oblique and transversalis muscles, which are practically in the same line. To facilitate this blunt separation a thin membranous sheath on the outer surface of the internal oblique should be incised in the line of the proposed separation. As this separation of the muscular layers according to the direction of their fibers is in a different line from that of the aponeurosis, we may not get quite as much room from a given length of skin incision as if we incised the muscles. But by varying the direction and force of the retraction of the edges of the wound almost an equal amount of room is obtained. Moreover, we can readily enlarge the intermuscular incision by incising the sheath of the rectus toward the median line and retracting the muscle in the same direction. The blunt *intermuscular incision* is an almost absolute safeguard against hernia, as the muscles come naturally together and close the wound, and the more the muscles contract the closer come the edges of the wound. It is useful for colostomy on the left as well as for appendectomy on the right side.

In the *upper part of this area*, an oblique incision, nearly parallel with the costal margin, is nearly in line with the nerves and cleavage lines of the skin, permits the blunt separation of the internal oblique and gives a fairly good exposure of the parts about the liver on the right side and the stomach or spleen on the left side.

To expose the liver, gall-bladder, etc., an oblique incision from a point below and external to the ensiform cartilage, 12 mm. ($\frac{1}{2}$ in.) or more to the inner side of the costal margin, to a point half an inch above the tip of the eleventh rib will only divide the ninth thoracic nerve. The same is true of a vertical incision through the middle or outer part of the

rectus muscle from a point 12 mm. ($\frac{1}{2}$ in.) below the lower border of the eighth costal cartilage to a point 5 cm. (2 in.) above the umbilicus. For the same purpose Bevan's incision is serviceable, consisting of a vertical incision, along the outer border of the right rectus, whose lower end may be prolonged obliquely, outward, near the level of the umbilicus, and whose upper end, 18 mm. ($\frac{3}{4}$ in.) below the costal margin, may be prolonged obliquely inward and upward by incising the sheath of the rectus and retracing the muscle. When much room is required for the safety of an operation the incision must be enlarged or added to where and in what way it is necessary, but in general the above considerations should apply. For local anesthesia the most suitable incisions are the incision in the linea alba and the oblique incision at the sides, for there are no nerve trunks in the former and the latter incision is parallel with them.

The Regions of the Abdomen.—The abdomen has been *arbitrarily divided* into *nine regions,* so that the viscera of these regions may be localized with reference to the surface area of these regions. Of course, the relation of the viscera to the overlying surface is only approximate, for the position of the viscera has a wide range of physiological variation in different subjects or in the same subject at different times. This regional division may be of service in medical education, but in practice we determine the position of viscera by palpation, etc., and by reference to well-defined landmarks.

To aid the more precise description of the position of pathological or medicolegal findings the regions might be of more service. Unfortunately there is confusion and variation instead of uniformity in the boundaries of these nine regions, so that the method is useless for accurate description.

The two vertical and the two horizontal planes which mark off these regions must be fixed with reference to landmarks easily located on the living body.

As usually described, the **vertical planes** *pass* through the middle of the inguinal (Poupart's) ligament, and nearly correspond with the lineæ semilunares in the two upper zones.

The **upper horizontal plane** is best drawn as a *subcostal plane* connecting the lowest points of the tenth costal cartilages of each side.

The **lower horizontal plane**, as usually given, passes through the two *anterior superior iliac spines.*

It is as important to know the viscera which are cut by these planes as the viscera in the areas bounded by them.

The *vertical planes cut* from below upward *on the right side,* the apex of the cecum, small intestine, transverse colon, kidney, and gall-bladder (often); and *on the left side,* the sigmoid flexure, small intestine, kidney, transverse colon, pancreas, stomach, and spleen.

The *upper horizontal plane passes through* the second (or third) lumbar vertebra behind, and runs 5 cm. (2 in.) above the umbilicus in front. The *viscera cut by it* are the stomach, transverse, ascending and descending colons, duodenum (lower curve), both kidneys, and the small intestine.

The *lower horizontal plane* (interspinous) *passes* at about the level of the top of the sacral promontory and *cuts* the cecum, small intestine, and sigmoid flexure.

The names and visceral contents of the nine regions marked off by the above planes may be seen in the following table. The adjacent parts of the lower iliac and hypogastric regions form the *inguinal region.*

RIGHT.	MIDDLE.	LEFT.
R. Hypochondriac.	*Epigastric.*	*L. Hypochondriac.*
Liver, greater part of right lobe. *Gall-bladder,* part of fundus (sometimes). *Kidney,* upper and outer part. *Colon, hepatic flexure* and part of *ascending colon.*	*Liver,* whole or greater part of left lobe, part of right lobe. Most or all of *gall-bladder.* *Stomach,* middle and pyloric regions, both orifices. *Intestines; duodenum,* first and second portions and end of third portion. *Small intestine. Transverse colon* (part of). *Pancreas,* head and body. *Spleen,* upper and inner part. *Kidneys,* upper and inner part. *Adrenals.*	*Liver,* sometimes part of left lobe. *Stomach,* fundus. *Spleen,* greater part. *Pancreas,* tail. *Kidney,* upper and outer part. *Colon, splenic flexure,* and part of *descending colon.*

HORIZONTAL PLANE AT LEVEL OF LOWEST POINT OF THE TENTH COSTAL CARTILAGES.

Right Lumbar.	*Umbilical.*	*Left Lumbar.*
Kidney, lower and outer part; *intestine; ascending colon; cecum* (part of); *vermiform appendix* (often); part of *ileum* and its termination.	*Kidneys,* lower and inner portion with *ureters; intestine,* third part *duodenum;* part of *jejunum* and *ileum;* greater part of *transverse colon;* part of *sigmoid flexure.*	*Kidney,* lower and outer part; *intestine, jejunum;* part of *descending colon;* part of *sigmoid flexure*

HORIZONTAL PLANE AT LEVEL OF ANTERIOR SUPERIOR ILIAC SPINES.

Right Iliac.	*Hypogastric.*	*Left Iliac.*
Intestine; ileum, part of; *cecum,* lower part of; *vermiform appendix.*	*Intestine, small intestines;* part of *sigmoid flexure;* upper part of *rectum;* tip of *cecum,* usually; *vermiform appendix* (often). *Bladder* in children and, when distended, in adults. *Uterus, fundus* and *appendages.*	*Intestine; small intestine;* part of *sigmoid flexure.*

The Umbilicus and Umbilical Hernia.—In early *fetal life* there *pass through* the *umbilical opening,* which is bordered by fibers of the linea alba, the urachus, the umbilical arteries and vein, and a loop of small intestine. Outside of the body these are bound together by embryonic tissue (Wharton's jelly) and covered with amnion to form the *umbilical cord.* Later the *intestinal loop retracts* within the abdomen, leaving

within the cord, for a time, the *vitello-intestinal duct,* which connects the end of the loop with the yolk sac. The proximal end of this duct may persist as a finger-like process, *Meckel's diverticulum,* connected with the lower end of the ileum, from 30 to 90 cm. (1 to 3 ft.) from the ileocecal valve.

Occasionally, from imperfect development, the fetal condition persists at birth, and a loop of intestine or an intestinal diverticulum projects a variable distance through the umbilical ring into the cord. This constitutes a **congenital umbilical hernia.** If care is not exercised in tying the cord, this projection may be tied or cut off, causing a *fecal fistula,* which may be proceded by obstruction if an intestinal loop is tied. Two or more cases of such an accident are on record. More rarely the hernial protrusion is larger and contains a larger mass of intestine or other viscera with a thin covering.

At birth the *cord is tied* a short distance from the belly wall and the proximal end shrivels, dries up, and in about five days *drops off at the same spot in all cases, i. e.,* the level of the abdomen, no matter where the ligature is applied. This is accounted for by the sphincter-like arrangement of elastic fibers around the umbilicus (especially on its deep aspect), which contract and shut off like a ligature the vessels passing through the ring, including those supplying the cord itself.

At birth and for some time afterward a *distinct ring* can be *felt at the umbilicus.* At the spot where the stump of the cord separates from the belly wall a *scar* forms which binds together the stumps of the umbilical vessels. The skin rapidly grows over this scar, which, when it contracts, throws the surface into folds, forming the *umbilical papilla.* It is on account of the creases between the folds that it is so difficult to make the umbilicus aseptic before operation.

As we *look at this puckered scar from behind* we see the converging obliterated umbilical arteries and the median urachus running to it from below (Fig. 101) and the empty umbilical vein running upward from it. At first there is a slight depression in the centre of the contracting ring, into which there is a little projection of peritoneum. During infancy a hernia may protrude through the cicatrix, not yet firm, in the still open ring, between the arteries and the vein, or above the latter. This is known as **infantile umbilical hernia.** It occurs in the first few months of infancy, and is due to frequent coughing, crying, or straining on account of constipation, phimosis, etc. If properly *treated* by being kept reduced it usually heals without operation, for the cicatricial contraction of the ring can then go on to final closure.

The umbilical vessels having become obliterated and reduced to fibrous cords in the first month of infant life, the abdomen grows more rapidly than these obliterated vessels, which, therefore, pull upon the umbilical cicatrix. The traction of the two obliterated arteries and the urachus is stronger than that of the vein, so that the fibrous cords representing all three vessels are pulled down to the lower margin of the umbilicus. The upper half of the scar is thin, while the vessel cicatrix, in the lower half, becomes the strongest part of the umbilicus and the latter

the strongest point in the abdominal wall. Consequently, in adult life an **acquired umbilical hernia** either protrudes through the upper part of the reopened ring or altogether above it, and is in reality a hernia of the linea alba, on the lower aspect of which appears the umbilical cicatrix. This form of hernia occurs most commonly in women after repeated pregnancies and in very stout individuals, owing to the stretching of the abdominal walls in both classes of cases.

On the deep aspect of the umbilicus, in about two-thirds of the cases examined,[1] are seen transverse fibers passing from the inner border of one rectus sheath to that of the other. They are known as the *fascia umbilicalis,* are adherent to the peritoneum, cover the deep surface of the umbilical vein, and represent a thickening of the transversalis fascia. In certain cases they are present only above and below the umbilicus, leaving the latter free and, theoretically, more exposed to hernia. But as acquired hernia occurs quite uniformly above the umbilicus, the common arrangement, where the fascia ends by a free margin a little above the cicatrix, may be equally favorable to hernia formation.

Richet[2] likened a canal-like space above the umbilicus, between the linea alba and this fascia, to the inguinal canal in relation to hernia formation. But the analogy is purely an imaginary one.

The *umbilical papilla,* or cutaneous cicatrix proper, is at the bottom of a depression which is due to a lack of subcutaneous fat in and immediately about it. It corresponds to the original fibrous ring of the umbilicus, derived from the tissues of the linea alba. The layers of the abdomen in this cicatricial area, *i. e.,* skin, aponeurotic scar tissue, fascia transversalis, and peritoneum, are so thin and closely adherent that, when stretched out by a hernia, we can hardly avoid opening the peritoneal sac, unless by incising well above, below, or laterally. The superficial fascia is practically wanting.

In congenital and many infantile herniæ the omentum is not found in the sac, for at this period it has not developed as low as this. In the acquired form it is nearly always present and frequently adherent. The colon is often present and incarceration is common.

Coverings of Umbilical Herniæ.—Congenital herniæ, embryonic tissue of the cord and an amniotic layer continuous with the skin at the ring. There is no true sac.

Infantile herniæ, peritoneum, forming the sac, transversalis fascia, skin. (The superficial fascia is so scanty as to be practically wanting.)

Acquired herniæ, the same as the infantile variety with the addition of the superficial fascia and the fibrous tissue of the umbilical scar or of the linea alba, for, as a rule, the hernia is really through the linea alba above the scar.

The *subperitoneal tissue* is so small in amount as to be omitted, for the peritoneum is here very adherent to the fascia.

In fetal life the **urachus,** *derived,* like the bladder, from the stalk of the allantois, has a *lumen* connected with that of the bladder, etc. Accord-

[1] Sachs, Virch. Arch., Band cvii.

[2] Anat. Chirurgicale, 5th ed., p. 745.

ing to Luschka, a total obliteration of the lumen of the urachus is not the rule, but an unobliterated part is usually found. This may be connected with the bladder or shut off from it. Occasionally such a patent portion opens as a *fistula at the umbilicus.* A probe passes a variable distance down the urachus, and a seromucous secretion, not urine, is discharged from the opening of the fistula. I have met with a few such cases, which are readily closed by scraping and cauterization.

A few cases are on record where the fetal *canal of the urachus* has *remained open* from the bladder to the umbilicus, so that on micturition the urine would stream from the latter when its passage through the urethra was impeded. In case of stricture of the urethra its function could be performed by such a urachus.

Another abnormal condition observed is a *reopening of the urachus* during retention of urine, thus allowing urine to escape at the navel and relieve the retention. But, as Hyrtl suggests, it is not unlikely that in such a case the urachus was patent as far as the umbilicus. *Urinary calculi* have also been found *in the urachus,* where the latter connected with the bladder, and in one case a stone was removed from the bladder by the aid of a finger passed through a patent urachus. In the lower part of the median line the peritoneum is separated from the abdominal wall by the urachus, so as not to be in direct contact with it.

The Inguinal Region and Inguinal Hernia.—The **boundaries** of this region are Poupart's ligament below, a horizontal line from the anterior superior iliac spine above, and internally the median line or, for practical purposes, the outer border of the rectus muscle. The several **layers** of the belly wall are essentially the same here as elsewhere anteriorly, except that (1) the *intercolumnar fibers and fascia* are closely joined to the outer surface of the external oblique aponeurosis, and (2) the *conjoined tendon,* representing the internal oblique and transversalis muscles, arches over from the outer half of Poupart's ligament to the iliopectineal line and the pubic crest. This leaves bare of these muscles the inner half of the ligament and a narrow semilunar space above it, corresponding to the inner two-thirds of the inguinal canal.

The superficial inguinal lymph nodes are below Poupart's ligament over Scarpa's triangle (see p. 491).

What gives this region its importance is the presence of the **inguinal canal,** an *oblique passageway* through the abdominal wall for the spermatic cord in the male and the round ligament in the female. This canal, like many others in the body, is not an actual but a *potential canal,* a breach or track forming a *weak spot* in the abdominal wall along which a hernia may be protruded. An open canal is a pathological condition due to a hernia, etc.

The Inguinal Canal.—The inguinal canal in the male is *formed by* the passage of the processus vaginalis and the testis through the abdominal wall, which then closes down snugly on the spermatic cord, which follows the testis.

It should be remembered that the *testis,* etc., does not break through each layer as a bullet through a board, but *the several layers* are evagi-

nated as a pouch before it and stretched out to form a laminated covering of the testis and the cord.

The peritoneal pouch, evaginated with the musculofascial layers through what is to be the inguinal canal, forms the **processus vaginalis**. This precedes the descent of the testis through the canal. The testis is from the outset outside of the peritoneum, having developed behind it, so that it descends alongside of and outside of the processus vaginalis through the inguinal canal and so into the scrotum. (See Scrotum and Testes.)

The two ends or openings of the canal are called the *abdominal rings*. The inferior and mesial one is known as the *external ring* because it is superficial, though more internal or mesial than the internal ring.

The External or Superficial Abdominal Ring.—The external or superficial abdominal ring is where the cord, or round ligament, passes through the aponeurosis of the external oblique and spreads apart two fasciculi of this aponeurosis called *pillars of the ring*. A triangular gap is thus formed with its base downward and inward over the spine and outer part of the crest of the os pubis. The **lower** and outer fasciculus or "**pillar**" of the ring blends with and, in fact, is the inguinal (Poupart's) ligament. It is *attached to* the pubic spine internally and the fascia lata below. It is the stronger and more posterior pillar, and on it rests the cord or round ligament. The upper and inner "pillar" is attached to the pubic crest. So-called **intercolumnar fibers**, arching upward and inward between the two pillars, bridge across and round off the outer angle where the two pillars meet, and bind the latter securely together so as to prevent their further separation. These intercolumnar fibers are joined together by a thin membrane into a fascia, the *intercolumnar fascia*. From the margins of the ring this fascia is prolonged over the cord and testes as the *external spermatic fascia*. It represents the attenuated covering furnished by the external oblique aponeurosis.

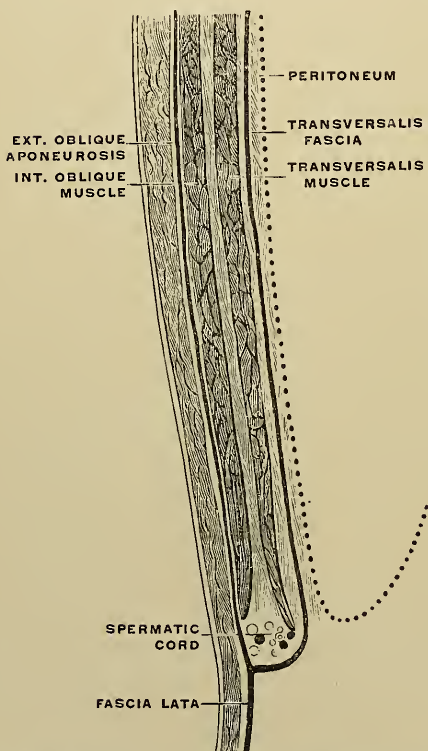
The base of the triangular gap is rounded off by the **triangular fascia**, lying at a deeper level than the ring, and sometimes known as the posterior pillar. Thus the *external ring* is *oval*, with its long diameter obliquely vertical. It *lies* 2 to 3 cm. (1 in.) from the median line, above and just lateral to the pubic spine, and can readily be *felt* by invaginating the scrotum with the finger and following up the front of the cord.

It averages 2.5 cm. (1 in.) by 12 mm. (½ in.), though its **size** is very variable and it is smaller in the female than in the male. In cases of non-descent of the testis, or after its removal, the external ring may be narrowed or even obliterated. Normally it will admit the tip of the index finger in the adult, that of the little finger in the child. It is felt to be *enlarged in* flexion, adduction, and inward rotation of the thigh by means of the relaxation of the fascia lata and thereby of Poupart's ligament, the external pillar, which is attached to this fascia. Hence the thigh is placed in this *position for taxis or for examination* of the canal, also to see if a truss or bandage fits snugly enough to retain a hernia. Vice versa, it is *narrowed in* extension, abduction and outward rotation of the thigh by the traction of the fascia lata making tense the external oblique aponeu-

rosis. This position is one which may be employed after operations for hernia.

The Internal or Deep Abdominal Ring.—The internal or deep abdominal ring is where the cord passes *through the transversalis fascia,* which is here called the infundibuliform fascia, because it has formed a funnel-shaped pouch for the testis and still presents a slight pit or depression. The inner fascial margin of this depression forms a prominent crescentic edge, due to the traction of the vas deferens as it bends inward and downward into the canal.

Fig. 100



Sagittal section of anterior abdominal wall through the middle of the inguinal canal. (Tillaux.)

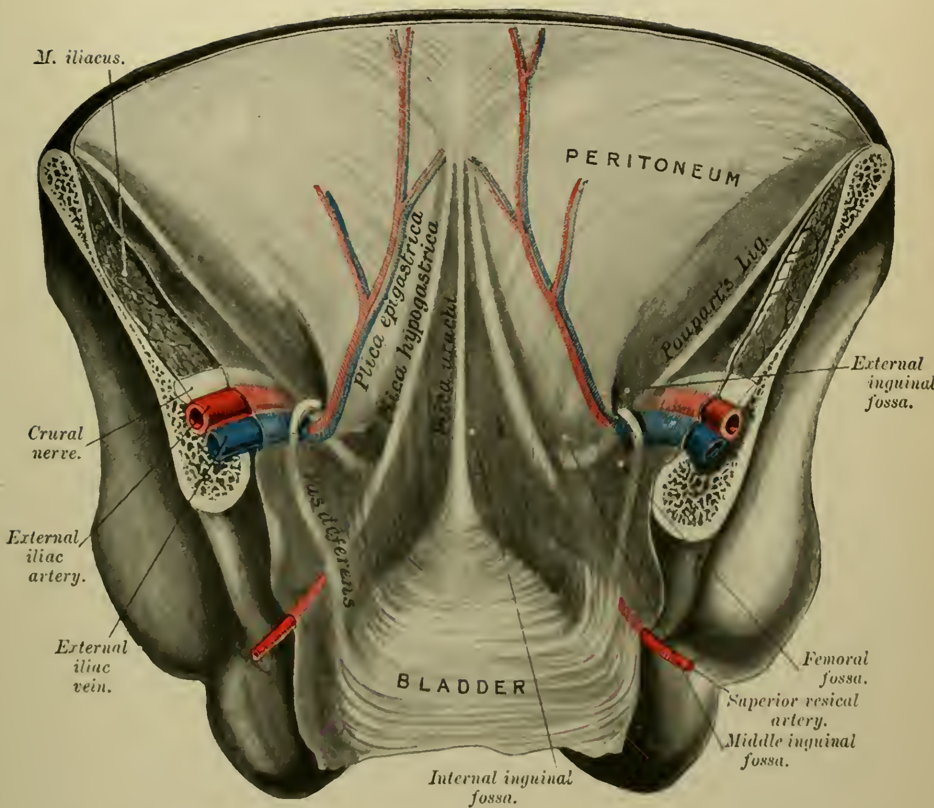
This ring *lies* somewhat over 12 mm. ($\frac{1}{2}$ in.) above Poupart's ligament at a point slightly internal to its centre. It is oval in *shape,* with its long diameter directed vertically. The *transversalis fascia* is *not broken through* by the passage of the testis, but is one of the layers of the pouch evaginated to receive it, and forms the *infundibuliform or internal spermatic fascia,* whose *upper opening, the internal ring,* is closed around the cord or round ligament.

The Inguinal Canal.—The inguinal canal, extending obliquely between these two rings, measures 4 to 5 cm. ($1\frac{1}{2}$ to 2 in.) in *length* in the male and 5 cm. (2 in.) in the female. Its *direction* is somewhat more vertical than Poupart's ligament, and its oblique passage through the abdominal wall serves as a valve to lessen the chance of a hernia entering it. Its *size* varies with that of the cord or round ligament which occupies it, hence it is smaller in the female. The *right canal* averages *larger* than the left, a fact that may help to explain the preponderance of hernia on the right side.

Walls of the Canal (Fig. 100).—*In front* lie the aponeurosis of the external oblique and, in the outer third, the lower fleshy fibers of the conjoined tendon. These same fibers arch above it. *Behind* lie the transversalis fascia and, opposite the inner half of the external ring, the conjoined tendon and the triangular ligament. *Above it* is the conjoined tendon, *below* is the gutter formed by the junction of Poupart's ligament and the transversalis fascia, above which lies the cord at a distance which

PLATE XXX

FIG. 101



Posterior View of the Anterior Abdominal Wall in its Lower Half. (After Joessel.)

The peritoneum is in place, and the various cords are shining through.

increases, as we proceed outward, to 12 mm. ($\frac{1}{2}$ in.) or more at the internal ring. In this space we may incise to open iliac abscesses or expose the external iliac artery.

Fat is *abundant* in the *subperitoneal tissue* behind the rear wall of the canal, so that masses of fat are commonly found adherent to the outer surface of the neck of a hernial sac, especially on its mesial side.

Lying in this subperitoneal tissue are the **deep epigastric** vessels, structures of great practical importance, which pass *behind the canal just mesial to the internal ring*. Between the internal ring and these vessels the transversalis fascia is very strong; internal to the vessels, where a direct hernia makes its way forward, it is much weaker.

Besides the front walls of the canal as above given, other tissue layers, derived from the layers of the abdominal wall which formed the evaginated pouch, form the *coverings* of the *spermatic cord or of a hernia*. Thus the infundibuliform portion of the transversalis fascia is prolonged down the canal as a tubular covering of the cord, etc., and the lower fibers of the internal oblique, in the conjoined tendon, spread out in front and at the sides of the cord, as the *cremasteric muscle and fascia*. Occasionally the pouch is evaginated between instead of beneath these fibers, in which case the cremaster is found behind as well as in front and at the sides of the cord, testis, etc.

Inguinal hernia is the passage of one or more of the abdominal viscera through, or partly through, the abdominal wall, following in whole or in part the inguinal canal. When *complete*, it emerges at the external ring. They comprise 95 to 97 per cent. of all herniæ in the male and 55 to 60 per cent. in the female. There are *two principal groups* of inguinal herniæ, according as the point at which they pass through the transversalis fascia lies *external or internal to the deep epigastric artery*.

Inguinal Fossæ (Fig. 101).—As we look at the peritoneal surface of the abdominal wall in the inguinal region we see on each side two longitudinal ridges or folds of the peritoneum, which converge toward a median fold, due to the urachus, as they ascend toward the umbilicus. The most lateral fold is the *plica epigastrica*, a fold of peritoneum elevated by the deep epigastric artery and forming the lateral boundary of *Hesselbach's triangle*, whose mesial boundary is the outer border of the rectus muscle. Somewhat nearer the middle line is the *plica hypogastrica*, due to the obliterated hypogastric artery.

In the inguinal region these elevated folds mark off certain *depressions or fossæ*. External to the epigastric fold is the **external inguinal fossa**, at the bottom of which we see a funnel-shaped depression of the peritoneum, which corresponds to the internal abdominal ring. Through the peritoneum we can usually see the vas deferens, coming from within and looping around the epigastric artery to enter the ring, where it joins the spermatic vessels coming from above. Between the epigastric and hypogastric folds is the **middle inguinal fossa**, which *corresponds to* the rear wall of the inguinal canal, as far as the inner half of the external ring, and to the weaker part of the transversalis fascia. Between the hypogastric fold and the outer border of the rectus muscle is the **internal**

inguinal or supravesical fossa, *corresponding to* the inner half of the external ring.

When a *hernia* pushes through in the external fossa we call it an *external, indirect or oblique inguinal hernia;* when in the middle or internal fossa, it is known as an *internal or direct inguinal hernia.* These two primary varieties of inguinal hernia are named internal and external with reference to the relation of the neck of their sacs to the deep epigastric artery, and direct and indirect or oblique with reference to their straight or oblique course through the parietes. The resistance of the abdominal wall is less at these fossæ than elsewhere.

External, Indirect or Oblique Inguinal Hernia.—These *follow* the course of the *inguinal canal.* They constitute 95 to 97 per cent. of inguinal herniæ. An *incomplete hernia,* or one not passing beyond or only just beyond the external ring, is called a **bubonocele** from the bubo-like swelling. A *complete hernia* sooner or later descends into the scrotum, and is called *scrotal.* At the external ring, as in the canal, it lies in front and slightly to the outer side of the cord, which it follows to the scrotum. The **coverings** of such a hernia are the same as those of the cord in the same situation, *i. e.,* skin, superficial fascia, intercolumnar fascia (also called external spermatic fascia), cremasteric fascia, infundibuliform fascia (sometimes called internal spermatic fascia). The last three layers form what is sometimes known as the *fascia propria,* a term of no great importance. The serous sac is derived from the peritoneum at the bottom of the external fossa, and is separated from the fascial layer by subserous tissue.

These herniæ are *pear-shaped,* with the small end above, at the narrow oblique neck in the canal. The *contents* are not characteristic; almost any of the lower movable viscera may be within the sac. Small intestine (enterocele) is commonly found, omentum (epiplocele) often, and the latter is apt to adhere to the sac and make the contents irreducible. Not infrequently, especially in congenital herniæ, the cecum and appendix are found in herniæ on the right side and occasionally on the left side. A part of the bladder is occasionally found in a hernia (p. 421).

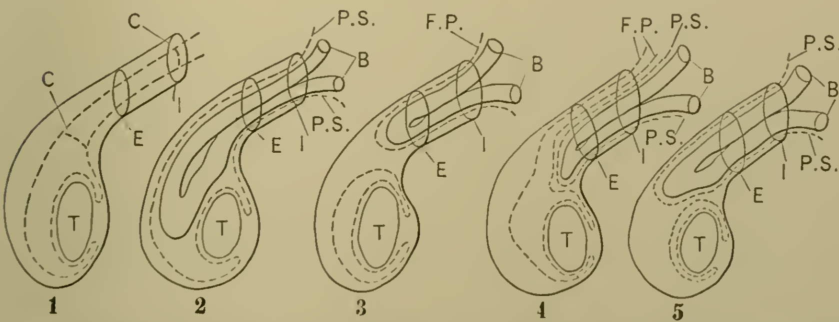
Despite the long and oblique course of the neck of *external inguinal herniæ,* in a canal whose muscular walls would naturally tend to close it, and despite the more direct course of internal inguinal herniæ through an anatomically weak part of the abdominal wall, the former *occur much more commonly.* They are especially *common in early life,* and this fact, as well as their greater frequency, is to be *explained* in great measure *by congenital conditions.* In fetal life one ring lies in front of the other, to facilitate the passage of the testis, so there is scarcely any canal. In early childhood the inguinal canal passes more directly and less obliquely through the abdominal wall than in the adult, a fact which favors the formation of hernia. The adult obliquity of the canal is acquired only after the development of the pelvis is completed.

Varieties of Externnl Oblique Inguinal Hernia due to Congenital Defects in the "Vaginal Process."—After the testis has reached the scrotum, in the eighth month of fetal life, the neck and upper part of the peritoneal

pouch, the processus vaginalis, tend to become closed, down to the upper end of the epididymis. It is normally reduced to a small cord of fibrous tissue, lying among the elements of the cord, which is attached to the bottom of the funnel-shaped depression of peritoneum in the external fossa. This *closure proceeds* usually *from two points*, the internal ring and just above the epididymis, commencing, as a rule, at the former point. Part of the pouch between these two points may remain open and give rise to an "*encysted hydrocele of the cord*," if fluid collects in it.

1. Sometimes the vaginal process does not close, but remains continuous with the peritoneal cavity. A hernia may descend into this process as a *sac* which is *preformed or congenital*. Hence this variety is known as **congenital inguinal hernia**. Such a hernia need not occur at once or even shortly after birth, though it is very common at this period. It often develops after some years, in which case the upper opening of the process, remaining constricted or closed by a thin septum, is dilated or torn by

Fig. 102



Diagrammatic representation of the varieties of external inguinal hernia due to congenital defects in the vaginal process: 1, the processus vaginalis, showing the two points where closure of the upper part commences, at *C* and *C*; 2, congenital hernia; 3, hernia into the funicular process; 4, infantile hernia; 5, acquired hernia; *E*, external abdominal ring; *I*, internal abdominal ring; *P.S.*, peritoneal sac; *B*, herniated bowel; *P.F.*, funicular process; *T*, testis.

the hernia forced through it by some sudden strain. It may also occur when the testis has not descended, provided the processus vaginalis has passed into the scrotum. The presence of a congenital sac by no means necessitates the occurrence of a hernia. In congenital herniæ the *sac* is very *thin*, the *neck* long and *narrow*, and the parts about it have been little disturbed or distended, so that *strangulation* is relatively *more frequent* and severe in this variety than in the acquired form. Reduction by *taxis* may be *difficult* by reason of its long narrow neck. In the attempt at taxis pressure should be made upward then upward and outward, in the course of the canal, and then backward. As the natural tendency of a congenital sac is to close during early life, especially as the canal grows longer and more oblique, we can often effect a cure in children by keeping the contents permanently reduced.

2. The upper end of the vaginal process may close while the rest remains open, a condition which is the rule in early infancy. If under

such circumstances a hernia with its peritoneal sac is forced down, or, according to Lockwood's theory, a peritoneal sac is drawn down by the gubernaculum, such a hernia is called an **infantile inguinal hernia,** for it was first described in infants.

As the sac lies behind the open vaginal process we must pass through this process to open the sac, and in so doing we would *divide three layers of peritoneum,* two of the process and one of the sac. The variety is uncommon and unimportant. The hernial sac may occasionally project into or invaginate the vaginal process, giving rise to the term **encysted hernia.**

3. Again, the closure of the vaginal process may occur only below, just above the testis, and a hernia into this preformed sac is known as a **hernia into the funicular process.**

This *sac* is *congenital,* and it differs from the so-called congenital hernia only in the fact that in the latter the contents are in contact with the testicle, in the former they are separated by the septum, which has shut off the tunica vaginalis testis. Herniæ which become fully formed in a short time are of congenital origin. It is probable that in a majority of cases the sac of a hernia is of congenital origin.

4. Finally, those herniæ whose sac is formed anew from the peritoneum of the external fossa are known as **acquired external inguinal herniæ.** This variety *develops more slowly* and does not descend as low in the scrotum or come in such close contact with the testis as the congenital varieties.

Internal or Direct Inguinal Hernia.—Internal or direct inguinal hernia is one which *emerges* internal to the deep epigastric vessels and, as its name implies, *passes* directly forward through the abdominal wall where it appears to be weakest. Nevertheless, it is far *less common* than the indirect form, a fact *due to* congenital conditions, the presence of the cord in the canal and the funnel-shaped depression of peritoneum at the internal ring which act as predisposing causes of the indirect variety. Direct hernia *occurs most often* when the abdominal walls have lost their strength and are lax, as in old age, after any prolonged distention, or after emaciation following obesity. Its *point of exit* is usually in the *middle inguinal fossa,* opposite the external ring, *rarely* in the *internal fossa,* in which case it has been called "*internal oblique hernia,*" as its course is somewhat obliquely outward to emerge at the external ring. The *neck* of a direct hernia is usually *wide,* admitting one or two fingers, but the pulsation of the deep epigastric artery can rarely be felt to its outer side. *Strangulation* is *not common,* occurring most often at the external ring. **Its coverings** differ only normally from those of the external variety. *Transversalis fascia* takes the place of that local subdivision of it, the infundibuliform fascia. In place of the cremasteric fascia we have the *conjoined tendon,* except in certain cases where the hernia escapes beneath it or breaks through between its fibers without receiving a covering. If it escapes through the inner fossa, the *triangular fascia* may form one of its coverings.

Other features of this form of hernia may be best brought out by

observing the differences between an internal and an external inguinal hernia.

The *shape* of an internal inguinal hernia is globular on account of its short neck, that of an external is pear-shaped.

The *size* of the former is smaller, and it has little tendency like the latter to follow the cord or descend low into the scrotum. The *position* of the former is more internal, and it lies more internal to and in front of the cord instead of in front of and external to it. On reduction the *track of the neck* of the internal is short and straight, that of the external is oblique and longer. Also if the finger can be introduced through their deep openings, the *pulsations of the deep epigastric artery* may possibly though rarely be felt internally in external hernia and externally in internal hernia; while internally in the latter may be felt the edge of the rectus muscle.

The external form is often congenital, the internal never. The external form occurs especially in early life, the internal late in life.

From these differences it would seem an easy matter to *distinguish between the two forms*, and so it is where the relations of the various parts are not much disturbed, as in recent or congenital herniæ. But in *old external inguinal herniæ* the traction of an increasing weight on the inner side of the internal ring enlarges it on this side, brings it nearer or even opposite the external ring, and so *shortens the canal* and makes it *less oblique*. Also, if the rupture is irreducible, some of the diagnostic points will be wanting. Thus, it may be difficult or impossible to distinguish between the two varieties.

Hernia Operations.—The *incision* is made over the course of the canal, but somewhat more vertically, and extends for a short distance beyond it. It is laid out according to the landmarks we have given for the canal. The superficial external pudic artery is usually divided, but is of no importance. Several large veins, varying in size and number, may be met with crossing the line of incision. In recent or small external herniæ the point of constriction, if strangulation occurs, may be at the internal or external ring, but it is more often in the narrow neck of the sac itself, which must then be opened.

In the operation most often practised, that of Bassini, the dilated or enlarged canal is obliterated, so as not to leave an easy passageway for the recurrence of the hernia, and a new track is made for the cord.

How Are We to Recognize the Different Layers?—It is neither necessary nor always possible to distinguish all of them. After division of the skin whatever moves with the cut edges belongs to the superficial fascia, unless inflammation has rendered the latter adherent to the parts beneath. The external oblique aponeurosis can easily be told by its pearly shining oblique fibers. The cremaster, or conjoined tendon, is the only muscle usually exposed, and may be recognized by the attachment and direction of its fibers. Some difficulty may be found in determining whether the peritoneal sac has been opened or not.

In congenital inguinal herniæ the sac is more closely adherent to the fascial layer outside. This may enable us to know when we meet with

such a hernia, but it makes it more difficult to free the sac as well as to know when we have opened it.

How are we to distinguish between the sac and the intestinal wall?

1. The outside of the sac has not a shiny *smooth surface,* like that of the peritoneal surface of the intestine, but often shows attached to it little lumps of fat and shreds of areolar tissue belonging to the subperitoneal tissue.

2. The *vessels* on the sac run more vertically, those on the intestine circularly.

3. If we pinch up a fold between the fingers the *sac* is *very thin,* the intestinal wall thicker. The presence of *fluid* within the sac, in large amount in strangulated hernia, is also of great diagnostic importance.

In what direction should we not incise to relieve a constriction of the neck of an inguinal hernia? In the *external form,* not backward on account of the cord, nor inward on account of the deep epigastric artery. In the *internal form,* not backward on account of the vas deferens and bloodvessels, nor outward for fear of the deep epigastric artery. But as it is often impossible to distinguish between the two forms it is advisable in any case to incise as if it might be either variety, and not to cut backward, inward, or outward.

Hence we should incise *upward or upward and slightly inward, i. e.,* parallel with the deep epigastric artery. An extensive cut is unnecessary, several small cuts answer equally well. Incision of the neck of the sac is only called for in cases of strangulated hernia, and with care may be done from without as well as from within the sac. In fact, the former is now preferable, as the radical operation is almost always done in such cases.

Strangulation consists in the obstruction of the blood supply by the constriction. At first the venous circulation alone is obstructed. This causes swelling and increases the constriction and the arterial circulation becomes arrested. Paralysis of the intestines develops, which completes the existing obstruction to the passage of intestinal contents. Gangrene and perforation of the gut follow if the constriction is not relieved.

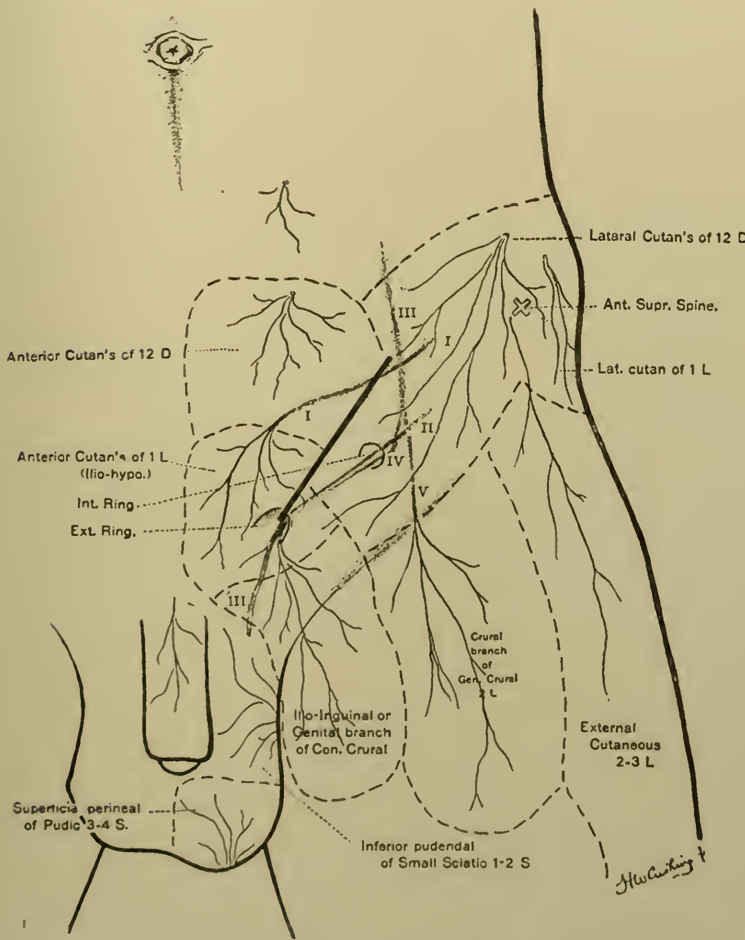
The nerves of and about the inguinal canal are important in connection with operations under local anesthesia. The line of incision involves the cutaneous distribution of the twelfth thoracic and iliohypogastric nerves. The latter emerges through the aponeurosis 3 to 5 cm. ($1\frac{1}{4}$ to 2 in.) above the external ring and supplies the skin near the inner end of the incision.

The ilio-inguinal nerve and the genital branch of the genitocrural nerve are generally found anastomosed in the canal, where they are seen in front of the cord or hernial sac on splitting up the aponeurosis. The cocainization of this common trunk at the outer end of the canal, or beyond, anesthetizes the entire scrotal contents, including the cord, hernial sac, and testis. There is no anesthesia of the scrotum, though it is generally stated that these nerves furnish a cutaneous supply to the scrotum. Division of this nerve trunk should be avoided in

herniotomy, for it results in paralysis of the cremaster muscle (see Fig. 103).

The Length of the Mesentery in its Relation to the Formation of a Hernia.—Mr. Lockwood has shown: (1) That with a *mesentery of normal length* the intestine may be drawn down through the external

Fig. 103



Inguinoscrotal nerves, their peripheral distribution and relation of main trunks to hernia incision: *I*, iliohypogastric; *II*, ilio-inguinal; *III*, genitocrural; *IV*, genital branch; *V*, crural branch. The heavy line represents the line of incision.

ring but not into the scrotum. (2) That the mesentery is *relatively longer in infancy*, decreasing rapidly in the second year, and averaging 20 cm. (8 in.) in length in the adult. In the congenital herniæ of infancy the mesentery may allow the gut to descend into the scrotum without first becoming lengthened, as is necessary in adults.

Interparietal Inguinal Hernia.—An interparietal inguinal hernia is one in which the sac or a diverticulum from it insinuates itself between the layers of the abdominal wall. It usually starts as an external hernia, but owing to some obstacle to the usual course it extends in the line of least resistance and makes its way between some of the layers of the abdominal wall, *i. e.*, between the peritoneum and the transversalis fascia (properitoneal hernia), between the transversalis fascia and muscle, between the internal and external oblique, or superficial to the latter. This form of hernia is most *apt to occur when*, for some reason, the *external ring is narrower than normal or is closed.* These conditions are present when the testicle has not completely descended, but is lodged just above or within the inguinal canal. The latter position of the testis especially favors the production of such a hernia, for the upper end of the canal is enlarged and commonly occupied by a pouch of peritoneum.

In such a hernia the tumor is flattened out. According to Tillaux, strangulation may occur by compression of the surrounding muscular layers, and taxis is more harmful than useful.

Reduction en Masse.—A hernia may be reduced by taxis together with its sac so that any constriction in the neck of the sac still exists. In such cases the sac may be pushed up between the peritoneum and the abdominal walls, or, if the infundibuliform covering is ruptured, in front of or behind the conjoined tendon which forms the upper boundary of the canal. It is not unlikely that some if not most of the cases in this group are really interstitial herniæ in which only the lower part of the hernia has been reduced.

Inguinal Hernia in the Female.—A pouch of peritoneum, the *canal of Nuck*, corresponding to the vaginal process in the male, descends in fetal life for some distance along the round ligament, and when, as sometimes happens, it remains open it may *form the sac of a congenital hernia.*

Inguinal hernia in the female is *most common* in infancy, early childhood, or after the first pregnancy. In the former case it is congenital, in the latter acquired, the canal having become distended during pregnancy, by the enlargement of the cord, which shrinks after childbirth and leaves the canal more lax. The round ligament bears the same relation to the hernial sac as does the cord in the male.

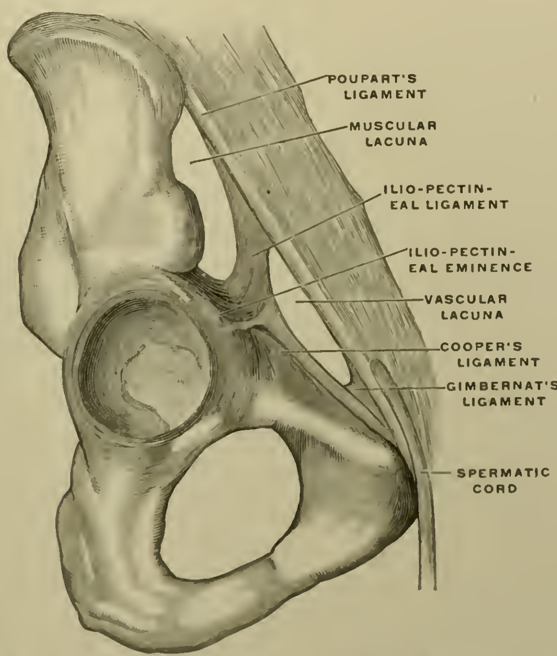
After emerging at the external ring a hernia may pass down into the labium majus. The *coverings* are the same as in the male except that the cremasteric layer is usually wanting, for the hernia commonly passes beneath the conjoined tendon. The *contents* are also the same except that the ovary or even the uterus, in part, may be found in the sac. Internal inguinal hernia is very rare in women.

Operations.—Operations in this region, except for hernia, are chiefly those to shorten the round ligaments, to open abscesses, or to tie the external iliac artery. To **shorten the round ligament** the *incision* is made as for hernia. The external ring is exposed, the tissue lying just internal to it is hooked up with a blunt hook, and the round ligament is sought for in this tissue. If the ligament cannot be so found, the canal should

be slit up and its contents caught up on the hook. After pulling the ligament down for a certain distance it becomes more fleshy and thick and a double sheath of peritoneum is drawn down with it, which may predispose to subsequent hernia.

Abscesses are principally of *two varieties,* to be spoken of in the study of the iliac fossa. One variety is *in the subperitoneal tissue* of the iliac fossa and is *limited inferiorly* by the line of Poupart's ligament. Here it raises up the peritoneum and may be *incised,* just above Poupart's ligament, without opening the peritoneum. The other, psoas abscess, is *beneath the iliac fascia* and *may point* above or below the middle or outer half of Poupart's ligament. When above the ligament it may be

Fig. 104



Vascular and muscular lacunæ beneath Poupart's ligament. (Joessel.)

exposed and opened after incising the transversalis fascia and pushing up the lower limit of the peritoneum, thus bringing to view the iliac fascia.

We proceed in a similar way *to expose* the **external iliac artery,** for which see Iliac Region, p. 309.

The Inguinofemoral Region and Femoral Hernia.—This region is the *passageway* between the upper part of the thigh and the region above. *Poupart's ligament bridges across* the concave iliopubic margin of the hip bone and thereby forms a space, mainly occupied by the iliopsoas muscle and the external iliac vessels in passing into the thigh. The fascia investing these structures subdivides the space into **compartments or lacunæ.**

The *largest and most external* of these is the **muscular compartment** *occupied by* the iliopsoas muscle and thc anterior crural and external cutaneous nerves. It is *bounded* externally and behind by the bony iliac margin between the anterior superior spine and the iliopectineal eminence; in front by Poupart's ligament and the iliac fascia, and internally by the iliac fascia (iliopectineal septum or ligament). The iliac fascia is firmly attached to the transversalis fascia and Poupart's ligament along the outer 4 cm. ($1\frac{1}{2}$ in.) of the latter, but then separates from them to pass to the iliopectineal eminence, where it is continuous with the pectineal fascia, *i. e.*, the pubic portion of the fascia lata. It is in this compartment that a *psoas abscess* passes beneath Poupart's ligament to "point" below it.

The *pectineus muscle* passes up a short distance above Poupart's ligament and may be said to *occupy* a **pectineal compartment,** *limited* behind by the horizontal pubic ramus and in front by the pectineal fascia. The upper limit of this fascia, along the iliopectineal line, is thickened by transverse fibers from Gimbernat's ligament.

The rest of the space is *triangular in shape* and, save the inner angle occupied by Gimbernat's ligament, constitutes the **vascular compartment.**

This is *bounded* in front by Poupart's ligament (*i. e.*, the *superficial femoral arch*) and the transversalis fascia, which is attached to Poupart's ligament, and is thickened by transverse fibers and known as the *deep femoral arch.* Behind the compartment are the iliac and pectineal fasciæ, continuous with one another. The external iliac vessels and the crural branch of the genitocrural nerve *occupy* this compartment in their passage into the thigh, the vein lying internal to the artery.

The vessels do not occupy the entire compartment, but there is an *interval* of 15 to 25 mm. ($\frac{3}{5}$ to 1 in.) between the vein and the outer margin of Gimbernat's ligament, which constitutes the **femoral ring,** through which a femoral hernia forces its way beneath Poupart's ligament.

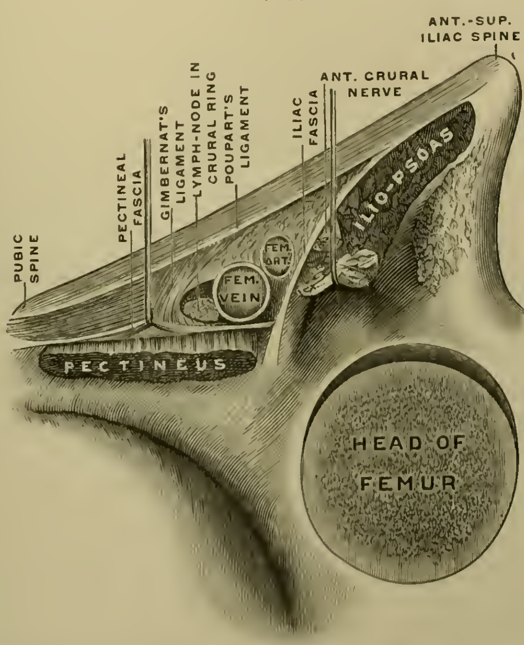
In passing beneath Poupart's ligament into the thigh to become the femoral vessels the *external iliac vessels carry with them* a fascial sheath, the **femoral sheath,** which bounds the vascular compartment and is continuous with the fascia lining the abdomen, *i. e.*, the transversalis fascia in front and the iliac fascia behind. These fasciæ are continuous with one another internally and externally so as to form a complete sheath. This sheath is *funnel-shaped,* wide above but closely embracing the vessels below, where it is continuous with their proper sheath. The width of the sheath beneath Poupart's ligament prevents compression of the vein and pinching or stretching of the vessels in movements at the hip.

The vessels occupy the outer side of the funnel and *leave* a pyramidal space, the **femoral canal,** on the inner side of the vein and separated from it by connective tissue, belonging to the fibrocellular or proper sheath of the vessels. This canal *measures* 12 to 18 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) in length, and tapers to its *lower closed end,* which is about *opposite* the upper end of the saphenous opening. It is only a *potential canal,* like the inguinal,

not a real one unless made so by a hernia or the knife. It represents a *weak spot* which forms the passageway of a femoral hernia.

The femoral canal is *bounded* externally by the femoral vein with a septum of connective tissue between, and on the other sides by the femoral sheath. It *contains* fatty and cellular tissue, lymphatics which penetrate its anterior wall and pass from the superficial to the deep inguinal nodes, and one or more lymph nodes. Its upper or *abdominal aperture* is the transversely oval *femoral ring*, mentioned above. The *size* of the ring varies, but is usually sufficient to admit the tip of the forefinger. It averages 15 mm. ($\frac{3}{5}$ in.) in diameter in the male, and is half

Fig. 105



Section of the crural canal and of the muscular and vascular compartments beneath Poupart's ligament. (Tillaux.)

again as large in the female, hence the *greater frequency of femoral hernia in women* in the ratio of three to one. Its *greater width in women* is not due to any greater width of the space beneath Poupart's ligament, for this is not wider, but to the smaller size of the muscles, occupying the muscular compartment, and of Gimbernat's ligament.

When *viewed from above* the *femoral ring* is seen to be covered by peritoneum, which may present a slight depression, the *fossa femoralis*. According to Tillaux, such a depression is not normal but pathological, the peritoneum being drawn down by an attached fat lobule belonging to the subperitoneal tissue, which is frequently the site of subserous lipomata.

On *removing the peritoneum* the ring is seen to be closed by the **septum crurale** (Cloquet), a condensed layer of connective tissue, continuous with the subperitoneal tissue and *perforated by* lymphatics passing from the inguinal to the iliac nodes. A small *lymph node* is sometimes found lying on it. Inflammation of this gland or of one in the canal has been mistaken for strangulated hernia, on account of a similarity of symptoms.

The boundaries of the ring are of great practical importance from their relation to the neck of a femoral hernia. To the *outer side* lies the vein in its sheath, elsewhere the boundaries are of firm fibrous structures. *In front* lies the superficial femoral arch (Poupart's ligament) and the deep femoral arch (see p. 302). *Behind* is the thin upper end of the pectineus muscle, resting on the horizontal pubic ramus and covered by the thickened upper end of the pectineal fascia. *Internally* there is a series of firm fibrous structures, attached to the iliopectineal line, as follows from below upward: the iliac portion of the fascia lata, Gimbernat's ligament, the triangular fascia, the conjoined tendon, and the deep femoral arch. These structures present a *sharp free margin* toward the ring.

Relation of Parts about the Ring.—The *spermatic cord* in the male and the *round ligament* in the female lie in loose tissue 5 to 6 mm. ($\frac{1}{5}$ to $\frac{1}{4}$ in.) above the *anterior margin* of the ring. The deep *epigastric vessels* lie above and to its outer side, between the internal abdominal and the femoral rings, distant about 12 mm. ($\frac{1}{2}$ in.) from the latter. The small pubic branch of this artery runs across in front of the ring, to ramify on the upper aspect of Gimbernat's ligament and of the os pubis. These structures are in danger of being divided by a free incision upward, but, according to Tillaux, not by an incision or incisions of 5 mm. ($\frac{1}{5}$ in.), which may subsequently be enlarged by the finger.

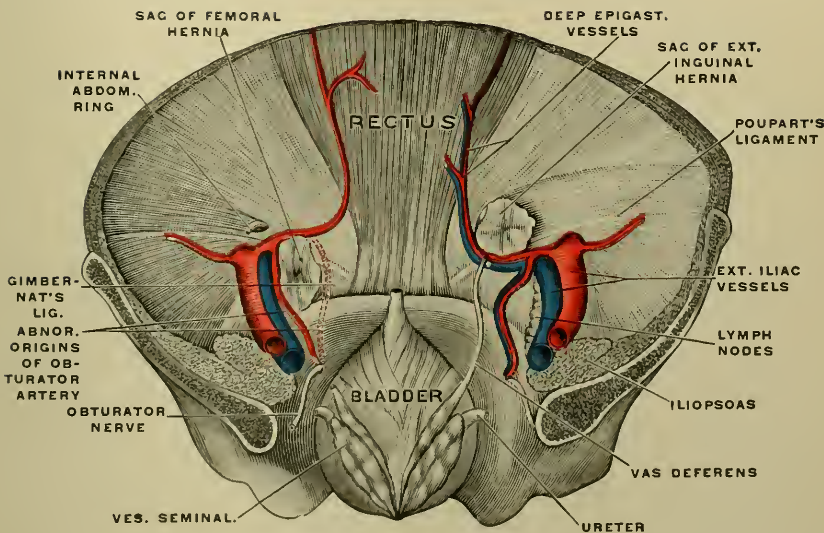
The *internal* and *posterior aspect* of the ring are usually *free* from important relations. Therefore, to relieve the constriction in a strangulated hernia we may *incise backward,* but little room is to be gained here, as only a thin layer of soft parts covers the bone. Hence we **incise inward**, bearing in mind the following *variations.*

Once in every three and one-half cases the *obturator artery* is given off as a *branch of the deep epigastric artery.* The *course of this branch* is commonly to the outer side of the ring, where it lies close to the vein, and not exposed to injury by incision, for we never incise outward on account of the vein. *Occasionally* (in 1 to $3\frac{1}{2}$ per cent.) the common trunk is longer, crossing in front of the ring, and the *obturator branch,* with its vein, passes back close to the *inner border of the ring* where artery and vein are exposed to injury by a free incision inward. Cases are recorded where such an injury has resulted fatally, and the reason why it does not occur more frequently seems to be that the vessels lie in loose tissue, 2 to 5 mm. from the edge of the ring, and may be readily pushed back before the knife, and also that multiple short incisions are often employed.

If the finger can be pushed through the ring the *pulsation* of such an

PLATE XXXI

FIG. 106



Rear View of Anterior Abdominal Wall, Showing Right Inguinal and Left Femoral Hernia. (Joessel.)

The obturator artery is given off by the epigastric, the dotted line on the left showing another, rarer and more important, form of this variety.

aberrant artery, lying internally, may perhaps be *felt.* It should be sought for so as to avoid the chance of an accident.

The *size and the tension of* the femoral ring and canal and of the saphenous opening, and hence the constriction of a hernia passing through them, *varies with the position* of the limb. They are *enlarged and relaxed* in flexion, adduction, and inward rotation of the thigh, and hence taxis should be tried in this position. In the reverse position these parts are rendered tense by the tension of the fascia lata and its traction upon Poupart's ligament.

Femoral Hernia.—Femoral hernia is *always acquired,* never congenital. It occurs almost exclusively in *adult life.* Though more common in women than in men in the ratio of 3 to 1, it is *less common in women than the inguinal variety,* contrary to the general impression. The weakening effect of pregnancy on the abdominal walls increases the liability of women to femoral hernia, so that it is more common after the first pregnancy.

Course and Coverings.—A pouch is gradually formed of the peritoneum covering the weak spot, the femoral ring. This forms the hernial sac and a covering is received from the septum crurale in passing through the ring beneath Poupart's ligament. The hernia *descends vertically* in the femoral canal to its *lower end,* opposite the saphenous opening. Here, taking the direction of least resistance, it *turns forward* and finally *upward* or *upward and outward* toward the anterior superior iliac spine, even as far as Poupart's ligament, receiving coverings from the femoral sheath and the cribriform fascia. It thus comes to lie beneath the skin and subcutaneous tissue.

Various *reasons* have been adduced *to explain the curved course* of the hernia: (1) The canal curves slightly with the concavity forward. (2) The downward course is limited by the lower limit of the canal and the firmness of the lower margin of the saphenous opening which is closely united with the femoral sheath and the cribriform fascia. (3) The constant flexion of the thigh. (4) The loops formed by the vessels passing to the saphenous opening prevent the further descent of a hernia. (5) The traction of the mesentery.

The *course* of a hernia should be *borne in mind in applying taxis* in the reverse direction for its reduction.

From the above we may summarize the **coverings** from without as follows: (1) skin; (2) subcutaneous tissue; (3) cribriform fascia; (4) anterior wall of the femoral canal (femoral sheath); (5) septum crurale; (6) peritoneal sac.

The *sac* of such a hernia comes to lie very close beneath the skin. One or more of Nos. 3, 4, and 5 may be *broken through* instead of pushed before the hernia so as to be wanting as a covering, and the *torn opening* of such layer or layers may be the *seat of constriction.* Nos. 4 and 5 (or 3, 4, and 5), often matted together and combined to form a single covering, were called *fascia propria* by Sir A. Cooper. It is often impossible to distinguish the separate layers as they may be thinned out and adherent to one another. In case of a hernia confined to the upper part

of the canal, the iliac portion of the fascia lata forms a covering between the femoral sheath and the superficial fascia in the place of No. 3.

A hernia confined to the canal is small, owing to the unyielding character of its fibrous walls, and is generally readily reducible, as the neck is as large as the rest of the hernia. After protruding at the saphenous opening into the loose subcutaneous tissue of the groin a femoral hernia is apt to be small and globular, but may attain considerable size.

The *contents* are not characteristic; *omentum* is very often present and apt to be adherent; intestine is less often present than in inguinal hernia, but is more likely to be strangulated. In the latter case the *seat of the constriction* is usually at the inner margin of the femoral ring or at the margin of the saphenous opening.

Herniotomy.—The *incision* may be parallel to Poupart's ligament and over the tumor, or vertical and on its inner side. Poupart's ligament should be exposed as a landmark. In large herniæ the overlying layers may be few in number or much thinned out, so the incision should be made with care. The amount of subperitoneal fat is sometimes very great, so as to simulate omentum, while the thinned fascia propria may be mistaken for the sac. In such a case, after enlarging the ring, the real sac embedded in fat may be reduced with its contents, and, if the constriction be.in the neck of the sac, the strangulation would not be relieved. This fat is so abundant that, in a tumor of some size, it is not always easy to find the small sac. We **incise the constriction** inward, inward and backward, or inward and forward (Cooper). The small external pudic vessels lie behind the hernia, and therefore are not cut by the incision.

In *Bassini's radical operation*, after removing the sac high up, the canal is closed by suturing the inner end of Poupart's ligament and the falciform edge of the fascia lata to the pectineal fascia (*i. e.*, the pubic portion of the fascia lata).

In the **diagnosis** between femoral and inguinal hernia, *Poupart's ligament* and the *pubic spine* are the two important *landmarks*. The neck of a femoral hernia is below the former and external to the latter; that of an inguinal hernia has the opposite relations, though it often crosses the spine, lying in front of it.

The diagnosis is easy in scrotal herniæ, in thin subjects, and when the herniæ are reducible so that the relations of the neck of the sac to the landmarks can be examined. It is easier in men than in women because of the greater ease of examining the inguinal canal in the former. In women, owing to its small size, the inguinal canal can only be satisfactorily examined when there is an inguinal hernia. In irreducible herniæ we must depend upon the position of the hernia relative to Poupart's ligament and the pubic spine, a femoral hernia being altogether below the former and external to the latter. In fat subjects we may not be able to feel Poupart's ligament even in its inner half, but the furrow of the groin nearly corresponds to it, or we may draw a line between its bony attachments, finding the pubic spine in males by invaginating the scrotum.

So-called **hernia adiposa** is not a real hernia but, from its position and

form, it may give difficulty in diagnosis here as with other forms of hernia. It is a *lipoma of the subperitoneal tissue*, which in its growth takes the same course as a hernia. It is *irreducible* and tends to draw the peritoneum after it, thus forming a pouch which may be the starting point of a true hernia.

Irregular and rare forms of femoral hernia may occur: (1) To the outer side of the artery; (2) hourglass-shaped hernia due to the escape of a part of the hernia through a rent in one of the covering layers, generally the cribriform fascia; (3) within the proper sheath of the vessels, etc.

THE POSTERIOR ABDOMINAL WALL.

Iliac Region.—This region, the lowest part of the posterior abdominal wall, corresponds to the iliac fossa and is *bounded* below by Poupart's ligament, internally by the pelvic brim (iliopectineal line), above and externally by the iliac crest. The right and left iliac fossæ are separated from each other by the pelvic cavity. It is comparatively small in children and attains its size about the time of puberty. It can be *examined* only through the abdominal wall, which should be relaxed by flexion of the thigh.

In studying this region layer by layer from before backward, we notice:

1. **Parietal Peritoneum.**—This becomes continuous with that lining the anterolateral abdominal wall along the iliac crest and Poupart's ligament, where it is loosely attached by means of the next layer so as to be easily *raised up*.

2. *The subperitoneal tissue* is here very *abundant* and loose, and contains more or less fat. It is continuous with the like layer in the neighboring regions of the abdominal parietes, the anterolateral region below and externally, the lumbar above and the pelvis internally (the latter including the tissue between the folds of the broad ligaments in the female).

Its *looseness favors the spread of abscess.* Such an abscess may originate in a viscus which occupies this region, the cecum or appendix on the right, the sigmoid flexure on the left. The infection may reach this layer by passing along the lymphatics or the tissue lying between the layers of peritoneum which attach the viscus. On the other hand, an abscess in this tissue may perforate and discharge into one of these viscera. Again, such an abscess may sink down from the lumbar region or rise up from the pelvis, as in cases of retroperitoneal pelvic abscess or pelvic cellulitis in the female.

Abscess in this tissue is *more common* on the *right side* owing to the presence of the appendix. As a rule, it *sinks to* the level of *Poupart's ligament*, and here it collects and displaces upward the peritoneum from the iliac fascia behind and the transversalis fascia in front and "*points*" *above Poupart's ligament* (Fig. 107). Just above this ligament it may be *opened by incising* the transversalis fascia and the overlying

layers without opening the peritoneum, as it is displaced upward. This was the course of many abscesses originating in the appendix, the so-called *perityphlitic abscesses,* before the adoption of the modern operation for appendicitis.

Many cases of *abscess* resulting *from pelvic cellulitis* open or are opened here. Occasionally pus collecting here escapes into the upper and inner aspect of the thigh through the femoral ring or along the iliac vessels, which lie in this layer, or it may sink into the pelvis.

Structures in the Subperitoneal Layer.—The external iliac artery and vein, spermatic or ovarian vessels, genitocrural nerve, ureter, and vas deferens, or round ligament.

Fig. 107

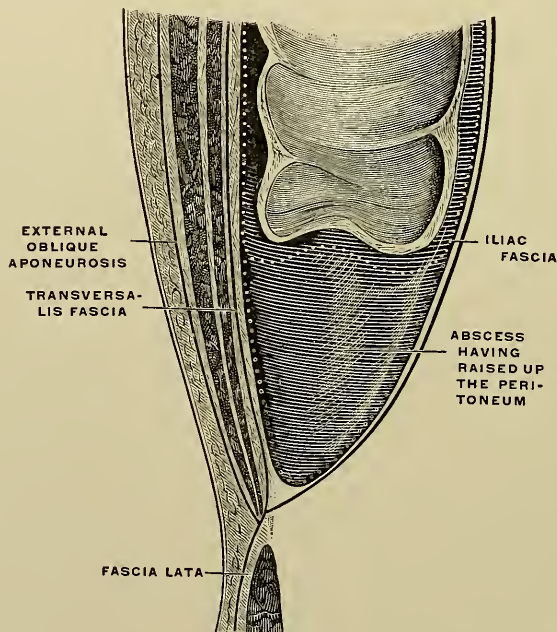


Diagram representing the displacement of the peritoneum by an abscess in the subperitoneal tissue of the iliac fossa. The white dotted line indicates peritoneum. (Tillaux.)

External Iliac Vessels.—The *course* of the artery is represented by a *line,* slightly convex laterally, from a point 12 mm. ($\frac{1}{2}$ in.) to the left of and below the umbilicus and directed downward and outward to Poupart's ligament, a little internal to its centre, or half-way between the anterior superior iliac spine and the symphysis pubis. The *upper* 5 cm. (2 in.) of this line would represent the *common iliac* artery, the lower two-thirds, or the part below the level of the lumbosacral articulation, the external iliac.

The **vein** lies to its inner side, passing behind it above on the right side so as to reach the outside of the right common iliac artery.

Position.—These vessels lie upon the inner border of the psoas muscle along the brim of the pelvis in a fibrocellular sheath, connected with the iliac fascia, which separates it from the muscle.

Relations.—The external iliac vessels are *crossed in front by* the sigmoid flexure on the left and the end of the ileum on the right side. The ureter sometimes crosses over their upper end instead of over the bifurcation of the common iliac vessels. The spermatic vessels and the genital branch of the genitocrural nerve lie upon the lower part of the artery for a short distance, and the deep circumflex iliac vein crosses it just above its lower limit. The vas deferens in the male, and the round ligament and ovarian vessels in the female, cross it to reach the pelvis. The crural branch of the genitocrural nerve descends on the anterolateral aspect of the artery.

These relations should be borne in mind in **ligature of the external iliac artery.** In this operation, whose principal indication is *femoral aneurysm,* the most important *relations* are those of the vein, for the ligature is passed from the venous side, and the relations to the loose subperitoneal tissue, for the latter allows the exposure of the vessel by permitting the raising up of the peritoneum from the iliac fossa through an incision along the lower or outer border of the region.

The **incision** may be made: (1) slightly above and *parallel with* the outer half of *Poupart's ligament*; or (2) *parallel with* and over the course of the *artery*, a little external to the course of the deep epigastric, so as to avoid the latter, and commencing a little above Poupart's ligament.

In (1) we *incise* the external oblique aponeurosis, the conjoined tendon along its attachment to Poupart's ligament, and the transversalis fascia, to expose the loose subperitoneal tissue, in which the artery lies in front of the iliac fascia. In this tissue at the inner angle of the incision the deep epigastric artery, if exposed, should be retracted inward and upward. The peritoneum is then bluntly detached from the iliac fossa, from behind Poupart's ligament upward and inward to the inner border of the psoas, which forms a convenient landmark for the artery.

There is *danger* of wounding the deep circumflex iliac vessels by incising too close to Poupart's ligament and of wounding the deep epigastric vessels by incising too far internally. Mesially the incision is not commonly carried beyond the level of the internal abdominal ring, as that is slightly internal to the middle of Poupart's ligament, but even if it should be, there is a full 12 mm. ($\frac{1}{2}$ in.) between the ligament and the ring, so that the latter need not be injured unless the incision is too high.

After separating the artery from the vein, through the loose tissue which forms a kind of sheath for it, the *artery* is *tied* by a *ligature passed* from within outward about 3 cm. ($1\frac{1}{4}$ in.) above Poupart's ligament, to avoid the proximity of collateral branches and important relations. The crural branch of the genitocrural nerve should not be included in the ligature.

In (2) the principle is the same, but the artery is exposed at greater depth, and there is more danger of hernia, while the deep epigastric and circumflex iliac vessels and the internal ring are in no danger. The

artery may also be tied higher up and the skin incision is farther from the groin in case an aneurysm bulges there.

At the present time the *transperitoneal method* is preferred by many. It also allows the ligature of the common iliac. The chief objections are those common to abdominal incisions and intraperitoneal operations. I have found McBurney's suggestion, the compression of the common iliac by an assistant's finger, introduced through an oblique intermuscular abdominal incision, most efficient and useful in amputation at the hip joint.

The **common iliac artery** may be reached and tied, extraperitoneally, by an extension of the *incision* (1) for the external iliac upward toward the lower ribs, or upward and inward toward the umbilicus. This operation is very rarely called for, but through such an incision the lower ureter may be exposed.

The **collateral circulation** after ligation of the external iliac artery is *derived from* the *anastomosis* of the deep epigastric with the internal mammary, obturator, lumbar, and lower intercostals; of the deep circumflex iliac with the iliolumbar; of the internal circumflex with the obturator; of the external circumflex with the gluteal; of the external pudic with the internal pudic, and other minor anastomoses.

The external iliac lymph nodes, eight to ten in number, extend in three linear chains along the anterior and inner aspect of the external iliac vessels. The internal chain, placed below and internal to the vein, is on the lateral pelvic wall. As the external iliac nodes *receive* the lymphatics from the inguinal nodes and those accompanying the deep epigastric and deep circumflex iliac arteries as well as lymphatics from the bladder, prostate, glans penis, clitoris, cervix, upper vagina, etc., they may be *enlarged* from infection from these sources. We may *palpate* them, when enlarged, through the abdomen, except in very fat subjects, and so determine the extent of the lymphatic infection in septic or cancerous cases. These nodes when enlarged may cause persistent *edema* of the lower extremity by pressure on the external iliac vein. They may be reached in the same way as the artery.

The Iliac Fascia.—The iliac fascia covers the iliopsoas muscle. It is attached to bone and fascia around the limits of this muscle, thus forming for it a single osseofibrous compartment. At the most dependent part the muscle and fascia pass into the thigh. The thin *upper part* sheaths the upper part of the psoas and is adherent to it. It ends above at the diaphragm in a thickening, the ligamentum arcuatum internum, and is attached, along the outer border of the psoas, to the anterior layer of the lumbar fascia. The *lower part,* covering the iliacus and the lower part of the psoas, is thicker and separated from the muscle by a *thin layer of fatty connective tissue* which favors the formation or spread of pus. In this loose tissue lie the anterior crural and external cutaneous nerves, and some muscular arterial branches. The large vessels are, therefore, separated by the iliac fascia from the principal nerves of this region, save the genitocrural. The lower part of the fascia is *attached* to the iliac crest externally and above, to the iliopectineal line internally, while inferiorly

it is adherent to the outer 4 cm. (1½ in.) of Poupart's ligament, and continues under the latter into the thigh as the sheath of the muscle as far as its insertion. *Internal to the muscle* it passes into the thigh behind the vessels, whose sheath it helps to form, and is *continuous with* the fascia covering the pectineus, *i. e.*, the pectineal fascia or the pubic portion of the fascia lata. Between the iliopsoas and the pectineus it sends back a *fibrous partition* to the pectineal eminence and the capsule of the hip (iliopectineal septum).

Although in surgery we find that abscesses do not always respect fibrous fascial planes, but sometimes break through them, this is less true of those beneath the iliac fascia, especially as they are mostly "cold" or tuberculous abscesses.

Abscesses *beneath the iliac fascia* are often known as "*psoas abscesses*" and have a quite definite *course*. They sink by gravity along the course of the muscle, pass under the outer half of Poupart's ligament, and *point* at the upper and anterior part of the thigh, external to the large vessels, where they may be safely *opened*. Occasionally they do not take this course, but may point elsewhere after penetrating the fascia. They may extend into the lumbar region, over the iliac crest into the gluteal region, over the pelvic brim into the pelvis, or along the inguinal canal into the scrotum, and find an exit in the parts named. They may also open above instead of below the fold of the groin. In other cases a psoas abscess passes lower into the thigh, probably following branches of the anterior crural nerve, where they pierce the sheath of the iliopsoas.

We call these abscesses "*psoas abscesses*" because most of them are *due to spinal caries* and make their way first into the sheath of the psoas. If the *caries* is *in the lumbar spine* direct extension into the psoas muscle readily occurs. The lumbar curve is likely to be flattened out in such cases. Instead of entering the psoas sheath such abscesses may pass behind it and enter and point in the lumbar region, or they may extend between the muscular and fascial planes of the anterior belly wall. If the *caries* is *in the thoracic vertebræ*, the pus descends by gravity in the posterior mediastinum along the front of the spinal column to the upper end of the psoas. This it penetrates, like a wedge, between its upper origins, *i. e.*, from the body and the transverse process of the first lumbar vertebra, at the same time passing under the ligamentum arcuatum internum. In time the pus may more or less entirely destroy the muscle, leaving the lumbar nerves free in a pus sac.

In inflammation of the iliopsoas, or in psoas abscess before the pus is evacuated, the *thigh is kept flexed*, for in this position the muscle is relaxed, the abscess is less tense, and the lumbar nerves less compressed and irritated. This *relaxation is due to* the fact that flexion of the thigh is the principal action of the iliopsoas; the outward rotation, sometimes associated with it, is due to other causes, for the iliopsoas is not an outward rotator. According to Hyrtl the iliopsoas cannot alone, or even with the pectineus, flex the thigh, so that in high amputation of the thigh the patient cannot flex the stump until the other flexors have become adherent to the scar or to the bone.

Abscess similar in course to the foregoing may arise in the iliac fossa which might properly be called "*iliac abscess*," but this term is more often applied to those in the iliac subperitoneal tissue.

In psoas abscesses the fold of the groin is partly effaced in its outer part, fluctuation may be obtained below Poupart's ligament, and a fulness is felt in the iliac fossa and, in thin patients, along the course of the psoas.

From the above we see that two well-marked forms of abscess occur in the iliac region, (1) in the subperitoneal tissue, and (2) beneath the iliac fascia, separated as to their position by the iliac fascia.

The **ilium**, forming the iliac fossa, *separates* this region from the gluteal region behind, hence pus in this region may sometimes gain access to the gluteal region by a perforation of the thin translucent bone. The posterior drainage of some cases of abscess in the iliac fossa, through a trephine opening in the bone, has in rare instances been practised, according to the principle of draining at the most dependent point, *i. e.*, in the supine position.

Tumors, especially enchondroma, osteo-enchondroma, and sarcoma, occasionally take origin from the iliac bone or its periosteum. *Fracture* from direct violence may involve almost any part of the ilium, the fossa, the superior spine or the crest. The latter may be separated entire as an epiphysis previous to about the twenty-fourth year, when it joins the bone. In fractures through the fossa the fragments are usually held in position by the muscles attached on either side, which act as splints. Owing to the many muscular attachments, absolute rest is required in the treatment of fractures of the ilium.

Lumbar Region.—The two lumbar regions, right and left, adjoin one another in the median line. They are bounded laterally by the external border of the external abdominal oblique muscles; above by the twelfth ribs; and below by the posterior half of the iliac crests. On account of its boundaries this area is known as the iliocostal space. The tip of the twelfth rib is, on the average, 5 cm. (2 in.) above the middle of the iliac crest, but this space may be widened by lateral flexion of the body, as it is in operations in this region.

Superficial View from Behind.—In the median line we see a vertical groove, the *spinal furrow*, which is due to the prominence of the erector spinæ mass on either side and to the attachment of the skin, by means of the subcutaneous tissue, to the tips of the lumbar spinous processes, which we feel in the bottom of the groove. The spinal furrow spreads out below into the angular interval between the gluteal muscles. The lateral margins of the erector spinæ muscle can be felt and usually seen, except in fat subjects. Lateral to the erector spinæ mass the surface is flattened. The anteroposterior displacement of one or more of the spines indicates an injury or a disease, probably caries of the bodies of the corresponding vertebræ.

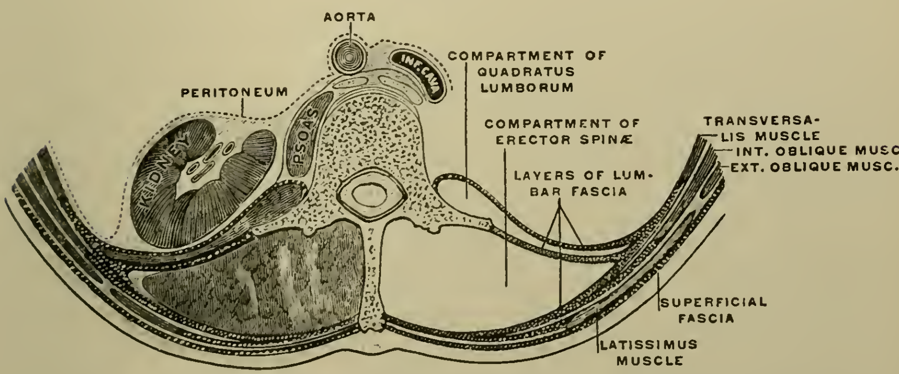
Normally the line of the lumbar spines and the contour of the lumbar region vertically is concave posteriorly and slightly more so in women than in men. In *hip joint disease*, when the joint is ankylosed in the

flexed position, this concavity is much increased on extending the thigh, giving rise to the deformity known as *lordosis*, and it is flattened out on flexing the thigh beyond the angle at which it is ankylosed. These are important diagnostic points, and are due to the very free flexion and extension in the lumbar vertebræ which occur when the pelvis is tilted and take the place of the similar movements in the hip.

A horizontal line connecting the highest points of the iliac crests corresponds to the spine of the fourth lumbar vertebra. In the interspace above (or below) this spine *lumbar puncture* is practised. This is below the spinal cord, which reaches to the top of the second lumbar vertebra.

The Subcutaneous Tissue.—The subcutaneous tissue is a thick dense layer containing comparatively little fat and connected closely with the skin, but only loosely with the fascia beneath, thus allowing large extravasations of blood or of a serosanguineous fluid from glancing blows.

Fig. 108



Transverse section at level of the second lumbar vertebra, to show the position of the kidney, the lumbar fascia, and the posterior attachment of the abdominal muscle (the external oblique is drawn too near the median line).

Superficial Muscles.—The **latissimus dorsi**, like the external abdominal oblique, is attached to the outer lip of the iliac crest. At the midpoint of the crest an *interval* usually exists between these two muscles, which is *triangular* in shape owing to their converging above. This triangle, with its base below at the crest, is known as the **triangle of Petit**, and is a weak spot representing a lack of one of the muscular layers. Hence it is that a rare form of hernia, **lumbar hernia**, occurs here, and it is a favorite spot for the pointing of lumbar abscesses. Its *floor* is formed by the internal oblique muscle, which overlaps the external oblique posteriorly, and thus comes in contact with the subcutaneous tissue in this small triangular area. Above, in another triangular area bounded by the twelfth rib above, the internal oblique externally, and the quadratus lumborum internally, the posterior aponeurosis of the transversalis is only covered by the latissimus dorsi muscle.

Both the internal oblique and the latissimus dorsi are attached to the dense posterior layer of the **lumbar fascia** (Fig. 108).

The lumbar fascia, the *posterior, middle, and anterior layers* of this fascia are *attached* mesially to the tips of the lumbar spines, the tips of the lumbar transverse processes, and the front of the bases of the latter respectively. Laterally they join together and thus form two osseofibrous *compartments* for the two vertical muscles of this region, the erector spinæ and the quadratus lumborum.

The posterior joins the middle layer of the fascia at the outer border of the erector spinæ. The middle layer, thus reinforced, joins the anterior layer of the fascia at the outer border of the quadratus lumborum. The combination of these three layers, about 7.5 cm. (3 in.) from the tips of the lumbar transverse processes, forms a fascia which gives origin to the transversalis muscle, and hence is called the **posterior aponeurosis of the transversalis muscle**, a name sometimes applied to the entire fascia. The posterior layer forms a part of or blends with the thick *vertebral aponeurosis* covering the muscles of the back.

The *posterior and middle layers*, where they form the sheath of the erector spinæ, are very thick and strong, hence abscesses seldom if ever penetrate the erector spinæ muscle unless they originate in the bones of the neural arch, with which the muscle is in contact. On the other hand, the *anterior layer*, covering the front of the quadratus lumborum, is very thin, and is in contact with the subperitoneal tissue in relation with the kidney and colon.

The lumbar fascia is very *variously described*, but the weight of authority makes the transversalis fascia continuous with the anterior layer of the lumbar fascia; the other differences of description are of no practical importance. The important point is that we have three fascial layers, forming two muscular sheaths, continuous with the posterior aponeurotic attachment of the transversalis muscle, giving attachment to other muscles and directing the course of abscesses, etc.

Abscess starting in the lumbar subperitoneal tissue may readily perforate the anterior fascial layer, enter and pass through the thin quadratus muscle, and perforate its posterior sheath external to the outer border of the erector spinæ. Or it may perforate the posterior aponeurosis of the transversalis external to the quadratus muscle. In certain cases this may be facilitated by the abscess following the last thoracic or the iliohypogastric nerves, where they pierce this aponeurosis, below the last rib and above the iliac crest respectively. In either case the abscess comes to lie under the internal oblique and its posterior aponeurotic attachment. The common course is then to perforate the latter and sink to the triangle of Petit or to the outer border of the erector spinæ, where it appears as a **lumbar abscess**.

Muscles.—The thick **erector spinæ** has a dense fascial sheath which we avoid opening in lumbar incisions, for little or no room is thereby gained and we thus avoid the danger of suppuration within the sheath. The erector spinæ mass *occupies* the entire vertebral groove on each side and projects beyond it laterally. Its *outer border*, limited by the union of the posterior and middle layers of the lumbar fascia, is readily felt about 8.5 cm. ($3\frac{1}{2}$ in.) from the middle line and forms an excellent landmark in making transverse or oblique lumbar incisions.

The thin flat **quadratus lumborum** is considerably broader than the erector spinæ below, and thus extends beyond it laterally, where it is itself overlapped by the internal oblique. At its upper narrower end it no longer overlaps the erector spinæ, which is here broader than below. The outer third or so of the thin quadratus muscle, unsupported by the erector spinæ, offers less resistance to protrusions from within than the inner two-thirds. The *outer border* of the quadratus lumborum forms the most valuable *landmark in lumbar operations.* This border is not vertical, but *inclines inward* as it passes upward. Just above the iliac crest it corresponds to a line drawn vertically from the middle of the crest, hence it corresponds to the position of Petit's triangle. Midway between the crest and the last rib it may be about 2.5 cm. (1 in.) internal to the above line.

Incisions.—Vertical lumbar incisions are made from a point 12 to 25 mm. ($\frac{1}{2}$ to 1 in.) mesial to the middle of the iliac crest, so as to meet the outer border of the quadratus about the middle of the lumbar region. This line of incision also corresponds to the course of the colon. This vertical incision is objectionable because it divides the lumbar and last thoracic vessels and nerves, which cross its course, and it affords comparatively little room. Hence an **oblique incision,** commencing in the costovertebral angle near the outer border of the erector spinæ, is preferable, as it parallels the vessels, the nerves, and the natural creases and cleavage lines of the skin of this region. If, as is often done, we incise just below the *twelfth rib,* the latter should be determined by counting from above, for Holl has shown that this rib is frequently rudimentary and so short as not to reach beyond the erector spinæ mass, so as to be mistaken for a lumbar transverse process. If the incision should then be made just below the eleventh rib the *pleura* would be *in danger* of being opened, an accident that has been recorded by Professor Dumreicher, of Vienna, and others. In these cases the lower edge of the pleura extends from the lower border of the last thoracic vertebra nearly horizontally to the lower border of the eleventh rib. Exceptionally also the pleura may project considerably below a normal twelfth rib, so as to require caution in any case at the inner and upper angle of the incision. The fact that we may have a correspondingly high level of the pleura with a rudimentary twelfth rib makes the above caution no less imperative in all cases.

The oblique incisions *extend laterally* a variable distance beyond the lumbar region, and *divide* in the superficial muscular layer, the latissimus dorsi, and the external oblique; in the next deeper layer the internal oblique and its posterior aponeurosis; and beneath this the transversalis and its posterior aponeurosis, including that part of it forming the dorsal layer of the sheath of the quadratus muscle. Retracting the outer border of the latter muscle inward, or incising it if necessary to gain more room, we incise its anterior fascial covering, and the transversalis fascia continuous with it, and reach the *subperitoneal connective tissue* in relation to the kidney and colon. It is in this tissue, which here contains much *fat,* that *perinephritic and pericolic abscesses* develop. The latter occur mostly on the right side, being due to the appendix. We have shown

above their most common course (lumbar abscess, p. 314), but they may also sink in the subperitoneal tissue into the iliac fossa or pelvis, and not infrequently they burrow through the diaphragm and parietal pleura and so enter the pleural cavity (p. 239).

The Vessels.—The vessels are the subcostal (twelfth or last thoracic), and the four lumbar arteries and their accompanying veins. Of these, the subcostal and first lumbar, and sometimes the last lumbar, pass outward in front of the quadratus lumborum, and behind the anterior layer of the fascia; the others lie behind the quadratus. Beyond the lateral border of this muscle they pass forward between the muscular layers of the anterior abdominal wall and anastomose with the vessels found there, as well as with those above and below. The *veins* on either side are connected by a vertical trunk, the *ascending lumbar vein,* which, continued into the azygos vein of each side, furnishes an anastomotic channel in case of obstruction of the inferior cava.

Lymphatics.—The superficial vessels empty into the inguinal nodes, the deep lymphatics accompany the bloodvessels and empty into the lumbar nodes along the abdominal aorta.

Nerves.—The twelfth thoracic and the iliohypogastric and ilio-inguinal branches of the first lumbar nerves *lie* in front of the quadratus lumborum and behind the anterior layer of its sheath; the first named a little below and parallel with the twelfth rib, the others nearly parallel with it and successively lower. The three nerves just named *pass* behind the kidney obliquely from within, outward and downward. *Pressure* upon them by a perinephritic abscess or a large tumor of the kidney may give rise to *pain* in the areas of their distribution. Thus in a case of perinephritic abscess I have seen the principal pain in the lateral gluteal region and over the outside of the hip, which are supplied respectively by the large lateral cutaneous branches of the last thoracic and the iliohypogastric nerves. The same renal lesions may cause *flexion of the thigh* from pressure on the branches of the second and third lumbar nerves supplying the iliopsoas and pectineus muscles.

The *obliquely transverse direction* of the vessels and nerves of this region renders them liable to division by vertical lumbar incisions, but not by obliquely transverse ones, a point of superiority of the latter incisions. The small size of the vessels renders their division comparatively unimportant.

Wounds.—Wounds of the region are *rare,* and are likely to be serious only when lateral to the erector spinæ mass, where the abdominal wall is thinner. Contusions may cause an injury to the viscera (kidney most often, possibly also the colon) without any appreciable sign of injury superficially.

In the reclining position the peritoneal aspect of the lumbar region is on a lower level than that of the iliac fossa, hence pus or other fluid, if free in the latter region, tends to gravitate to the former. This is to be carefully borne in mind in operating for appendicitis, where pus external to the cecum and colon should be prevented from gravitating into this region by gauze packing.

The Abdominal Cavity.—The *form* of the cavity is that of an oval with its larger end above. Owing to the obliquity of the diaphragm, the **main axis** of the cavity is oblique from above downward, forward, and to the right, and is directed to the right pubic spine. This is given as one reason for the greater frequency of hernia on the right side. The obliquity of the *axis of the pelvis* is from above downward and backward, so that in parturition and forced defecation or urination the body is flexed to bring these two axes in the same vertical plane, so that the abdominal pressure may act to the greatest advantage in the pelvis.

The abdominal cavity is *not identical with the peritoneal cavity,* for several of the abdominal viscera are *extraperitoneal,* being only partly covered by peritoneum (kidney, duodenum, etc.). Such viscera may be wounded or operated upon without involving the peritoneum, which is necessarily involved under similar circumstances in the case of the *intraperitoneal viscera* (stomach, small intestine, spleen, etc.). Similarly *peritonitis* is very apt to be caused by inflammation or perforative ulceration of the intraperitoneal viscera, but not necessarily by that of the extraperitoneal viscera. Thus a large perinephritic abscess very rarely involves the peritoneum, while inflammation of the appendix or perforation of the small intestine sets up a local or general peritonitis.

The Peritoneum.—The Parietal Peritoneum.—The parietal peritoneum *lines* the deep surface of the abdominal wall and the extraperitoneal viscera. It is thin above, thicker below and behind, where its more abundant and fatty subperitoneal tissue connects it loosely with the abdominal wall, allowing it to be stripped up in operations or by inflammations. At the umbilicus it is closely adherent to the belly wall and less adherent along the back of the linea alba. The parietal peritoneum is much more sensitive to pain than the visceral layer. This is seen in intraperitoneal operations under cocaine anesthesia. Strong retraction of the parietal peritoneum may cause discomfort, but if it is inflamed the same retraction and any handling may be very painful. The visceral peritoneum is practically analgesic unless traction is made on its parietal attachment. The peritoneum is *capable of great stretching* if it is effected gradually, as seen in the pregnant uterus, the distended bowel, a hernial sac, or an abdomen distended from various causes. According to Huschke, it is capable of *bearing a weight* of fifty pounds, and its *elasticity* is well shown by returning to its previous condition after removal of the weight as well as, during life, after the removal of ascites, large abdominal tumors, and the fetus at term. It is possible for the parietal peritoneum to be ruptured by an injury which does no damage to any of the viscera. *Inflammation* of the peritoneum and its results *interfere with* its distensibility and *elasticity,* and may thus disturb the functions of those organs which are covered by peritoneum and vary in volume (uterus, intestine, bladder, etc.).

Penetrating Wounds.—A penetrating wound of the abdomen is one which penetrates the peritoneum as well as the other layers of the parietes. Such wounds are much *more serious* than those which reach to but not through this layer, for while it is easy to set up inflammation (peritonitis)

from its inner surface, the outer surface may be bathed with the pus of an abscess or extensively stripped up in operations without ill effects. This difference is largely due to the relative delicacy and vulnerability of the endothelial inner surface, the spread of the infection to the opposed surfaces, and its diffusion by the movements of the intestines. The fact of penetration in an abdominal wound is often difficult to determine clinically, and, in the absence of definite symptoms, we are justified in enlarging bullet and stab wounds, rather than in exploring with the probe.

The resistance of the peritoneum to infection is usually greater the nearer normal its endothelial coat. It is lessened when the latter is subjected to traumatism, such as handling, rubbing, drying, and to chemical irritants, such as strong antiseptics. If infection does not occur under such conditions, the peritoneum exhibits its important property of forming plastic, adhesive exudates which become organized into firm adhesions. This also occurs in the presence of infection, and is largely a conservative process, for the infected or injured area is thereby isolated, which prevents a serious diffusion of inflammation. By the *stretching* of these adhesions there may be formed a variety of bands beneath which loops of intestine may be caught and strangulated. The tendency to adhesion is *made use of in intestinal suture,* in which the peritoneal surfaces are turned in so as to oppose one another. Firm adhesion occurs much sooner than when other soft parts are united by suture. Peritoneal adhesions, whether purposely formed or the result of inflammation, often show a tendency to become smaller, longer, and eventually to disappear, when the cause of irritation is removed.

The parietal peritoneum is somewhat less susceptible to infection than the visceral, and certain regions present greater facilities for limiting a peritonitis by adhesions so as to be less serious and more amenable to surgical treatment. Such regions are the pelvic, appendical, subhepatic, lesser sac, etc.

The Peritoneal Cavity.—The peritoneal cavity is merely a *capillary* interval between the contiguous surfaces of the viscera which are covered by peritoneum, and between them and the parietal peritoneum. It is a closed *serous sac* except in the female, where the openings of the Fallopian tubes connect it indirectly with the body surface. This sac contains just enough *peritoneal fluid* to lubricate the surfaces and diminish friction. As a result of various causes a large amount of serous fluid may be effused into the peritoneal cavity. This is known as **ascites** (from *ασκος*, a skin bottle), and *depends upon* (*a*) chronic inflammation from infection; (*b*) some abdominal tumors; (*c*) portal obstruction; and (*d*) general dropsy from cardiac, renal, or pulmonary disease. If the fluid is small in amount it collects in the flanks on lying down, or the hypogastric or inguinal regions on sitting up; if in greater amount the flanks are bulged, the umbilicus is prominent and the intestines float on top in whatever position the body is in. The fluid is dull or flat on percussion and sharply marked off from the tympanitic resonance of the intestines. Breathing may be easier in the sitting posture, for the compressible intestines then lie beneath the crowded-up diaphragm.

Tapping of ascites may be practised in the semilunar line, or preferably in the linea alba. When the fluid is partly withdrawn the end of the trocar is sometimes closed by the omentum or intestine, which can be dislodged by introducing a probe. As the withdrawal of the fluid, by reducing the intra-abdominal pressure, causes a distention of the deep abdominal veins, and thereby robs the heart of its wonted supply, syncope is liable to occur, but may be prevented by the pressure of an abdominal binder. A like result may follow a blow on the abdomen, owing to a paralysis of the vasoconstrictors.

The *surface of the peritoneum* is about *equal to* that of the skin. Hence we can understand its enormous *absorbing function*, taking up in one hour 3 to 8 per cent. of the body weight. An equal *transudation* or exudation may occur from very toxic or irritant substances. Fluids may pass through the endothelial layer in many places; solids are carried largely by leukocytes and are said to pass only through the intercellular spaces of the peritoneum covering the diaphragm and thence into the mediastinal lymph nodes. The presence of stomata is denied by Muscatello.

There is normally a force in the peritoneal cavity which carries fluids and foreign particles toward the diaphragm, regardless of the position of the body, though either retarded or favored by it. It has been proposed to make use of this fact to carry off septic peritoneal exudates by elevating the pelvis after operation. But, partly owing to the greater danger of toxemia, the opposite position (Fowler's position) is now employed, and the septic fluid gravitates to the pelvis, from which it may be drained off. The peritoneum in a healthy state is capable of *disposing of* a large number of *bacteria*, even of pyogenic varieties, without ill effects; but if there is a lesion of the membrane, or anything to arrest the normal absorption, so that the bacteria may stagnate and multiply, peritonitis results. Hence the importance, as above stated, of doing the least possible damage to the peritoneum.

If about the focus of a commencing peritonitis the surrounding parts become glued together by a plastic exudate on the peritoneal surface, the *peritonitis* may be limited or *localized*, as in most cases of appendicitis. If the adhesions are imperfect, or do not develop, or the focus is more diffused, the peritonitis is spreading until it becomes *general*. In peritonitis, especially in the more acute and general form, the muscular coat of the bowel and its nerve plexuses may become involved, causing intestinal paralysis. The result of this is constipation or complete obstruction of the bowels, and the gas, formed by the decomposition of the intestinal contents produces distention of the gut, *meteorism* or *tympanites*. This distention, in addition to the vasomotor paralysis, still further increases the paralysis. Hence the danger of giving opium, which increases these tendencies. *Tympanites* also raises the diaphragm so that the heart and lungs work with difficulty. The anatomical sources of infection which give rise to peritonitis are: (*a*) perforations or wounds of the viscera of the alimentary and urinary systems; (*b*) migration of bacteria through inflamed or strangulated gastro-intestinal walls; (*c*) infection through the Fallopian tubes, (*d*) through wounds of the abdominal wall, (*e*) or through the blood and lymph vessels, as in tuberculous peritonitis.

In peritonitis the least *pressure,* even of the bedclothes, may be *painful,* hence the patient lies with the shoulders raised and the knees drawn up, to relax the abdomen. The abdominal walls are rigid and boardlike, and the diaphragm is kept quiet to prevent movement of the viscera, respiration being thoracic. In *colic,* on the other hand, pressure relieves the pain, and the lax abdominal walls can be freely moved over the bowels.

The Visceral Peritoneum.—The visceral peritoneum besides covering the intraperitoneal viscera, forms folds known as the *mesenteries* and *false ligaments* to attach these viscera to the parietes. The visceral and parietal layers of the peritoneum are continuous by means of these folds, some of which deserve especial notice.

The Great Omentum.—The great omentum is the elongated *mesentery of the stomach* which is connected with its great curvature, or attached margin, and descends as an apron in front of the bowels, which it separates from the abdominal walls. In well-nourished persons it often contains considerable fat, which acts like a cholera band in maintaining an even temperature of the bowels. *In the embryo* the omental fold of the *mesogastrium* consists of four peritoneal layers which adhere together in infancy, and thereafter appear to consist of two layers containing fat and bloodvessels between them. The lesser omental sac extends down between the two anterior and the two posterior omental layers before they adhere together. The under layers, as they pass up in front of the transcolon and then back to the parietes, become adherent to the colon and to the upper layer of its mesocolon. The portion of omentum extending from the great curvature of the stomach to the anterior surface of the transverse colon, to which it is attached, forms the **gastrocolic ligament or omentum.** This and the transverse mesocolon prevent our reaching the posterior surface of the stomach without passing through one or the other of them. When we pull down the omentum the transverse colon and stomach are pulled down, and the former may be seen through it; and when we turn up the omentum we see the transverse colon attached to it. Hence the omentum may be used to find both the stomach and the transverse colon.

The omentum *extends down* a variable distance into the iliac and hypogastric regions, hence it is very apt to be *found in herniæ* as an epiplocele. This is said to be more common on the left side because the omentum is more developed on this side. It may be the only content of a hernia, especially of a femoral hernia, and it is almost constant in umbilical herniæ, except in the congenital and infantile varieties. (See Umbilical Hernia.)

The omentum generally *contracts adhesions to the sac* of a hernia in which it is present, provided the hernia is not kept reduced. Such herniæ thus become *irreducible,* and the omentum may form a kind of second sac about the gut. It often grows into a large conglomerate *fatty mass,* connected with the rest of the omentum by a narrow pedicle passing through the neck of the sac. When the omentum in a hernia is fit to be returned to the abdomen the intestine, if present, should be reduced first. In rare cases, especially in connection with a hernia in

which the omentum has been matted together and its upper part stretched out to a slender pedicle, the omentum may become twisted by external influences until it becomes strangulated. In a recent case of this kind I found four complete turns of the pedicle.

As a result of inflammation the omentum may contract *adhesions* to contiguous parts and so *form bands*, beneath which, as well as beneath adhesions to a hernial sac, the bowel may be caught and strangulated. *Strangulation* may also occur through *holes or slits* in the omentum. Omental adhesions may, under certain conditions, exert such a traction upon the stomach and colon as to produce functional disturbance. A benign effect of omental adhesions is seen where they help to limit inflammatory or hemorrhagic extravasations, or to occlude a perforation of the bowel due to disease.

The omentum, or sometimes a separated piece of it (*omental graft*), is occasionally similarly employed by the surgeon to fortify an intestinal suture, by being fastened over or around the latter. Ovarian tumors may be supplied with blood through an adherent omentum, in case the blood supply of the tumor is cut off by the twisting of its pedicle.

From its exposed position *wounds* of the omentum are common. It may plug a small abdominal wound and prevent the escape of other parts. After laparotomy it is well to replace the omentum over the bowels, when there is no contra-indication, so as to obviate intestinal adhesion in the line of the cicatrix. As the veins of the omentum empty into the portal circulation, it is fastened to the parietal peritoneum or in the subcutaneous connective tissue of the abdominal wall, in Talma's and Narath's operations respectively, to establish a collateral circulation in cases of portal obstruction.

The Small Omentum.—The small omentum *extending* from the transverse fissure of the liver to the small curvature of the stomach helps to *bound* the lesser peritoneal sac in front. Its *right thickened border* extends a variable distance onto the first portion of the duodenum, where it is called the **hepato-duodenal ligament.** The latter *bounds* the foramen of Winslow in front and *contains* between its two thin layers the portal vein the hepatic artery, and the common bile duct, the vein lying behind the other two, of which the bile duct is to the right of the artery. Its left extremity encloses the esophagus.

The Mesentery.—The mesentery is *attached to* the posterior abdominal wall for about 15 cm. (6 in.). This *attachment commences* at a point to the left of the second lumbar vertebra, on a level with the attachment of the lower fold of the transverse mesocolon, the end of the duodenum, and the lower border of the pancreas, and *extends* thence obliquely downward and to the right, with a slight convexity to the left, to the right iliac fossa, or to the right sacro-iliac articulation. This attachment is secondary or acquired; its real attachment is mesial and about the origin of the superior mesenteric artery, as in mammals below man. Occasionally, too, in man we find the embryonic type of the single median mesentery for the entire bowel.

At its lower end the *right layer* is continuous with the peritoneum

covering the ascending colon, and its *left layer* with the mesentery of the appendix. It forms a posterior longitudinal *partition* in the peritoneal cavity, and its *oblique course directs* hemorrhagic or other extravasations on the right side of the abdomen first into the right iliac fossa and on the left side into the pelvis. Hence the greater frequency of collection of blood in the right than in the left iliac fossa.

Between its two layers are *contained* blood and chyle vessels, nerves, fat in varying quantity, and lymphatic nodes, the latter especially near its attached border. In addition, a band of fibrous tissue and plain muscular fibers, descending from the left crus of the diaphragm to the end of the duodenum, passes down between the layers of the mesentery, and is of sufficient strength to support the weight of the intestines as well as to resist the pressure of the descent of the diaphragm. The name *suspensory muscle of the duodenum and mesentery* is suggested by Lockwood for this muscle. Like the omentum the mesentery may contain *tumors or cysts* of various kinds.

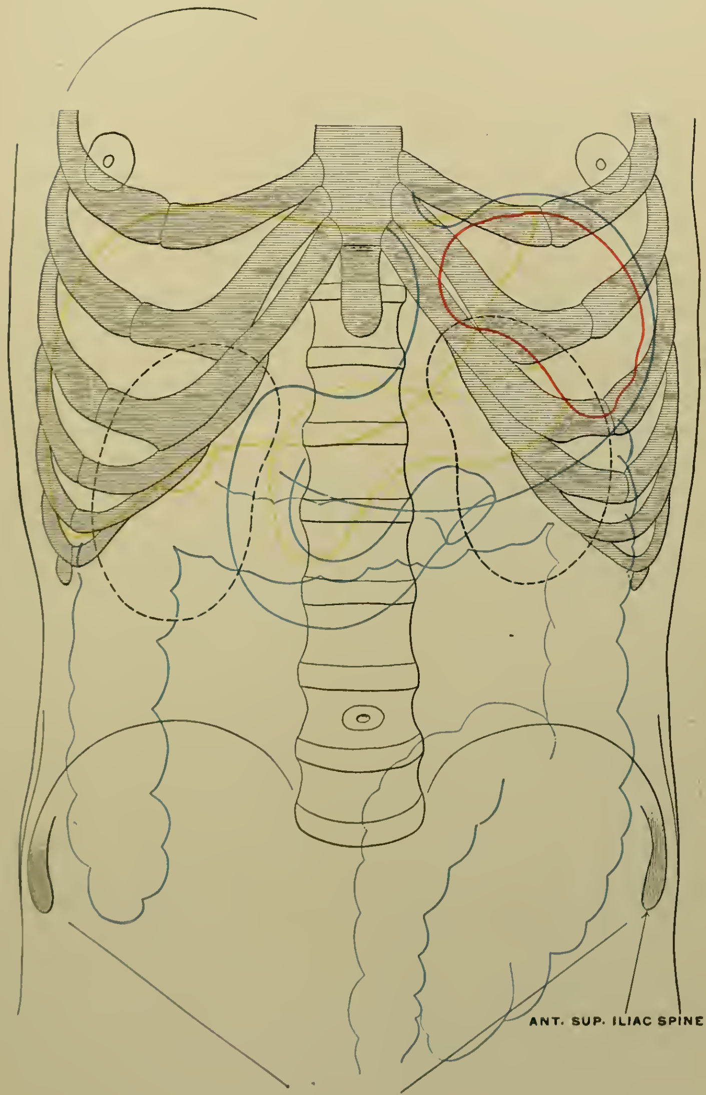
The length of the mesentery affords great *mobility* to the small intestine, allowing it to be displaced by tumors, etc. The length from its parietal to its intestinal attachment varies in different parts. Its *average length* is 20 to 22.5 cm. (8 to 9 in.), which it reaches not far below its upper end.

That part which is connected with the intestine between points 180 and 330 cm. (6 and 11 ft.) below the duodenojejunal junction attains its *greatest length, i. e.,* 25 cm. (10 in.) (Treves). This part of the intestine, as well as the lower ileum, is thus permitted to lie in the pelvis. According to Treves, when the mesentery is normal in length, no part of the small intestine can be dragged onto the thigh through the femoral canal (artificially enlarged) or into the scrotum through the inguinal canal, and no coil of intestine can be drawn out of the abdomen below a horizontal plane passing through the pubic spine. But Lockwood states that it is quite common in the adult to find that the small intestines will pass 3.5 cm. ($1\frac{1}{2}$ in.) beyond the right crural arch, up to the left crural arch, and one inch below the pubic spine. **Herniæ** in which the bowel occupies positions beyond the normal are common, and *require,* therefore, a *lengthening or lowering of the mesentery.* Whether this is always acquired, or may sometimes be congenital, has not been definitely determined. According to Lockwood, the mesentery is relatively longer in infancy, but rapidly decreases after the second year. The same author states that prolapse of the root of the mesentery may occur after middle age, and such a lowering, rather than a lengthening of the mesentery, is generally found in acquired herniæ. The length of the mesentery is an *important factor* to be taken into account *in the production of hernia.* The position of the mesentery allows intestinal hernia more freely on the right than on the left side.

The mesentery may contain *slits,* generally due to injury, or *round holes of congenital origin,* through which the intestine may be strangulated. The round holes are in an oval area of the mesentery of the lower ileum, included within an anastomotic arch between the ileocolic and the last intestinal branches of the superior mesenteric artery, which is often devoid

PLATE XXXII

FIG. 109



Outline of the Abdominal Viscera, showing their Position with Relation to One Another, the Ribs and Vertebræ. (Merkel.)

of fat, lymph nodes and visible bloodvessels, and is so atrophied that a knuckle of gut might easily be forced through it.

The mesentery is an excellent *guide* to lead us to either end of the small intestine, as in searching for intestinal lesions. Pulling forward a loop of the intestine and holding it vertically we trace its mesentery by sight and touch back to its parietal attachment to make sure that it is not twisted, or to untwist it if necessary. Assured that the mesentery is not twisted, by the finger remaining on one side until the posterior attachment is reached and followed into the parietal peritoneum of that side, we follow the intestine upward from the upper end of the loop to find the duodenojejunal junction, and vice versa to reach the lower end of the ileum.

The Transverse Mesocolon.—The transverse mesocolon is 7.5 to 10 cm. (3 to 4 in.) deep, and with the transverse colon, *reaches* from the posterior to the anterior abdominal wall except at the sides of the abdomen, where it is shorter. It forms an imperfect *transverse septum* between the lower part of the peritoneal cavity, containing the small intestine, and the upper part containing the liver, stomach, pancreas, and spleen. To a certain extent and for a time it may limit a peritonitis on one side from extending to the other. This protection is also increased by the omentum which is attached to the colon above and descends over the front of the small intestine. The transverse mesocolon *bounds the lesser peritoneal sac* below, so that in order to reach the posterior wall of the stomach, to expose an ulcer on this surface as well as to do a posterior gastroenterostomy, we divide the mesocolon vertically or parallel with its bloodvessels.

The **lesser peritoneal sac,** between the stomach, small omentum and gastrocolic ligament in front and the pancreas, etc., behind, *extends* on the left to the spleen and the left kidney. It *opens into* the general peritoneal cavity by the *foramen of Winslow.* The latter normally admits two fingers and through it an internal hernia may pass and become strangulated (Rokitansky, Blondin). This opening may become narrowed or closed, especially in inflammation. In case of closure a kind of cyst may be formed, according to Malgaigne and Begin. Subdiaphragmatic abscess involving the lesser sac may be due to gastric, duodenal, or colic perforation or pancreatic disease. The lesser sac may be opened through the small omentum, the gastrocolic omentum or the transverse mesocolon.

THE ABDOMINAL VISCERA.

The Stomach (Figs. 109, 114, 121, 123).

The Shape.—The shape of the stomach is like that of a somewhat flattened pear, bent near its smaller end. The *esophagus opens* into it at the right side of its larger end, so that the latter projects, as the *fundus,* about 7.5 cm. (3 in.) to the left of and 3 to 5 cm. (1¼ to 2 in.) above the esophageal orifice, while the *pylorus,* or the opening into the duodenum,

is at the smaller end. Therefore the length of the lower or left border is the greater, hence the name **greater curvature.** The **lesser curvature** the upper or right border, *measures* from 7.5 to 12.5 in. (3 to 5 in.), and is only one-third or one-fourth the length of the greater curvature. The latter is convex until we approach the pyloric end, where there is a slight indentation, between which and the pylorus there is a slight bulging, the *antrum pylori* (or pyloric portion), 7.5 to 10 cm. (3 to 4 in.) in length. The lesser curvature is concave except over the antrum, where it is slightly convex.

The *pylorus* can be *seen* as a slight constriction and *felt* as a thickening. Its location is best identified by the position of a thick-walled vein which extends across three-fourths of its breadth from below and meets, or nearly meets, a similar vein from above (Mayo). It is the narrowest part of the alimentary canal, having a *diameter* of 12 mm. ($\frac{1}{2}$ in.), hence many objects may be swallowed which cannot pass the pylorus and must be removed from the stomach by gastrotomy. This is especially common among lunatics, and the number and variety of articles swallowed by them is remarkable. It is also remarkable in some instances how large an object can be swallowed and pass the pylorus. Needles swallowed find their way through the stomach and bowels and appear at various points in the body. The terminal, 18 to 25 mm. ($\frac{3}{4}$ to 1 in.), the so-called pyloric canal of Jonnesco, appears never to become noticeably dilated, nor does it take part in the grinding function of the antrum, and hence is less exposed to the effects of injury and of the acid gastric contents. The thickening of the circular fibers, which alone produces the valve, is gradual as seen on the gastric side, but abrupt on the duodenal. It is quite probable that the pylorus is normally closed and that its opening is an active process. The pylorus normally admits the tip of the index finger with the invaginated stomach wall, but it is liable to *obstruction* or *stenosis* from several causes. The *antrum pylori* is elongated so that when empty and contracted it resembles thick-walled intestine. The *esophageal* is also called the *cardiac orifice* from its close relation to the heart. The *two surfaces* lying between the two borders are nearly symmetrical; the ventral one looks also upward and the dorsal one downward.

The **shape** *changes with age;* thus, some say that it is nearly cylindrical *at birth* and that the fundus, although it grows rapidly in the first year, does not attain full development until late in childhood. Fetal stomachs, however, may possess a well-developed fundus. In the female the stomach is relatively narrower and often more vertical. No definite senile changes occur. The *shape varies with* the degree of *distention.* In slight distention the fundus and cardiac portion are exclusively affected. As the distention increases the antrum also becomes distended, but the constriction between it and the cardiac portion persists until the distention is almost complete. During digestion this *constriction* almost completely separates the cardiac and pyloric halves. In the empty state the cardiac portion appears more spindle-like, more or less flattened from before backward, and the pyloric half-cylindrical, from the uniformly

active contraction of the stomach wall. This is probably the normal shape of the empty stomach during life. We can attach no *clinical significance* to the general shape of the stomach except to abnormalities, such as those due to diverticula, bands and scars, and *hourglass contraction.* The latter may be either pathological, due to contraction following chronic ulcer, or, rarely, congenital in origin. Diverticula are very rare.

The Size.—The size of the stomach *varies* with the age, sex, and degree of distention, as well as in certain pathological conditions. The *average capacity* at birth is $1\frac{1}{5}$ ounces (38 c.c.); at three months, $4\frac{1}{2}$ ounces (150 c.c.); at six months, 6 ounces (190 c.c.); at twelve months, 9 ounces (280 c.c.); at eighteen months, 12 ounces (380 c.c.). In the adult, according to Ewald, its normal limit of capacity is 1600 to 1700 c.c., and it cannot be distended by more than 100 c.c. in addition to this. In *gastrectasis*, or dilatation of the stomach, the capacity may be much increased. Dilatation of the pyloric portion is very rare, it is the cardiac portion which is principally involved in distention and dilatation of the stomach.

Normally when full its *oblique or longest diameter measures* 25 to 30 cm. (10 to 12 in.), its greatest *vertical diameter* (at the cardia) 15 cm. (6 in.), its *anteroposterior diameter* 10 to 12 cm. (4 to 5 in.) at the fundus and 3 to 4 cm. ($1\frac{1}{4}$ to $1\frac{3}{4}$ in.) at the antrum pylori. The distance between its two orifices varies from 7.5 to 15 cm. (3 to 6 in.). When empty and uniformly contracted it is scarcely larger in diameter than the transverse colon. In the female the stomach is smaller than in the male. The *weight* of the stomach is about $4\frac{1}{2}$ ounces (140 gm.).

The Position.—The position of the stomach *varies* more than that of any other viscus, except the small intestine, owing to its mobility and varying size. It *lies* in the left hypochondrium and the epigastrium, the fundus being in the former, the rest of the stomach in the latter, region. Only in occasional instances does it extend into the right hypochondrium.

The **cardiac orifice** is found behind the seventh left costal cartilage, 2.5 cm. (1 in.) from the median line, to the left side of the tenth or eleventh thoracic vertebra (ninth or tenth thoracic spine), and 11 cm. ($4\frac{1}{2}$ in.) from the anterior belly wall. It descends about 2.5 cm. (1 in.) in forced inspiration. Occasionally the cardiac orifice is found in the median line or even somewhat to the right of it. I have found it in this position in a case of gastrostomy for esophageal stenosis, and other cases are reported. This orifice is nearer the anterior than the posterior surface of the stomach by one-third of its anteroposterior diameter. It is distant 39 to 40 cm. ($15\frac{1}{2}$ to 16 in.) from the incisor teeth.

The **fundus** extends 3 to 5 cm. ($1\frac{1}{4}$ to 2 in.) higher than the cardiac orifice and its upper limit *corresponds to* the level of the sixth left chondrosternal joint, to that of the eighth intercostal space in the scapular line, and to the ninth or tenth thoracic vertebra. Its *highest part lies* directly beneath the left dome of the diaphragm, behind and above the apex beat of the heart. Its close relation to the left lung and the heart explains the interference with their function when the stomach is distended, as with flatulence, which causes shortness of breath and palpitation of the heart. Many imagine they have heart disease when the

real trouble is indigestion. Owing to the position of the fundus the stomach is sometimes wounded in wounds of the lower part of the pleural cavity involving the diaphragm.

The **great curvature** in its upper or left part is covered by the diaphragm, which separates it from the lung, the sinus of the pleura, and the thorax as we follow it from above downward. It crosses the left costal margin about the junction of the ninth and tenth costal cartilages. Inferiorly it extends to a point 2 to 4 cm. ($\frac{3}{4}$ to $1\frac{1}{2}$ in.) or two fingers' breadth above the umbilicus, and further to the right it ascends along the median edge of the gall-bladder. A normal stomach fully distended may even reach to the umbilicus, and in cases of **gastrectasis,** or dilatation of the stomach, the great curvature may reach any level between its normal position and the symphysis. This condition is *due to an obstruction at the pylorus* from cancerous newgrowth, cicatricial stenosis following an ulcer, thickening of the circular muscle of the pylorus in some forms of dyspepsia with hyperacidity and spasm of the pylorus, the pressure of an extrinsic tumor, etc. The enlargement can be readily *made out by* inspection, palpation, and percussion after distending the stomach with air, by a bicycle pump attached to a stomach tube. The great curvature may also reach a *low level* in **gastroptosis,** in which the entire stomach is displaced downward owing to the lengthening of the lesser omentum and the other supports of the stomach. It is favored by the use of corsets. This condition is, not unlikely, at times more of a vertical enlargement (without the transverse) than a displacement. The stomach may be somewhat pulled down by the traction of the omentum adherent to the sac of a hernia.

On the other hand, when it is *entirely empty,* as in cases of stricture of the esophagus, the stomach is *high up* under the left lobe of the liver and the costal cartilages and far back in the abdomen, so that the transverse colon projects up in front of it from below and (according to Sédillot) the anterior border of the spleen overlaps it from the side. In such cases it may be hard to *find,* but this can be done (1) by following up the under surface of the liver to the small omentum, and down the latter to the stomach, or (2) by pulling down the omentum and following it up to the stomach over the colon, which we distinguish by the longitudinal bands and the appendices epiploicæ. On account of its position the stomach is much less exposed to injury when empty, and the injury is less dangerous because there is little extravasation of its contents.

The **lesser curvature** *lies* under cover of the left lobe of the liver except in cases of gastroptosis, when it is displaced below it. It descends nearly *vertically* in front of the left crus of the diaphragm and the left side of the last two thoracic vertebræ, from the esophageal orifice to the antrum, where it turns quite sharply and passes transversely to the right, at the level of the first lumbar vertebra, and then slightly upward to the pylorus. Three-fourths or four-fifths of the stomach lie to the left of the median line.

The **pylorus** is *covered by* the quadrate lobe of the liver 3 to 4 cm. ($1\frac{1}{5}$ to $1\frac{3}{5}$ in.) to the right of the median line and 7 cm. ($2\frac{3}{4}$ in.) lower than

the cardiac orifice or the sternoxiphoid articulation. It is more *mobile* laterally than vertically, and its radius of mobility is 2 to 3 cm. ($\frac{3}{4}$ to $1\frac{1}{4}$ in.). It *lies* near the median line, in line with the right border of the sternum when the stomach is empty; farther to the right (7.5 cm. [3 in.] according to Braune) when it is full. In general it *corresponds to* a point near the end of the eighth right costal cartilage, to the level of a line drawn between the bony ends of the seventh ribs in front, and to the upper border of the first lumbar vertebra (or the twelfth thoracic spine) behind. The difficulty of palpating tumors of the pylorus is explained by its being covered by the liver, except occasionally when it is displaced downward by the newgrowth before the latter becomes adherent above. When the stomach is distended the *antrum* may extend farther to the right than the pylorus itself.

The **axis of the stomach** is now generally considered *more vertical* than formerly supposed, especially that of the cardiac portion. This fact, perhaps, combined with more or less gastroptosis or gastrectasis, accounts for the sword-swallowing feats. Good authorities, however, claim that it is more horizontal, especially in the empty stomach, passing from behind at the summit of the fundus forward to the right and slightly downward, while in the distended state the axis is more oblique (45 degrees) (Birmingham). The axis of the stomach is sometimes more vertical in infants, retaining some of the vertical position of the embryo, and exceptionally it remains so in the adult.

The **anterior surface** of the stomach is in *contact with* the diaphragm and the anterior thoracic wall, which covers the fundus; to the right of this, with the liver above and the abdominal wall below. The liver covers the pylorus and the parts just below the lesser curvature, and leaves a more or less **triangular area** where the stomach is *in contact with the abdominal wall.* This triangle is *bounded* on the left by the eighth and ninth costal cartilages; on the right by the free margin of the liver, passing from the ninth right to the eighth left costal cartilage; and below by the transverse colon, or a line joining the tips of the tenth costal cartilages. The latter has a distinct tip which, when pressed over the ninth cartilage, gives a peculiar crepitus to the finger.

Through this triangle we reach the stomach in the various **operations** on that viscus. The *incision* may extend above the right border of the triangle, for the free margin of the liver can be retracted upward. The *line of incision* may be vertical, in the median or semilunar lines or through the rectus muscle, or oblique, parallel with and 2.5 cm. (1 in.) from the left costal margin. In the latter case the part of the incision external to the rectus divides the three flat abdominal muscles. Behind the rectus we meet with the superior epigastric artery, which we avoid or ligate. Of these operations the most important are gastrotomy, gastrostomy, gastro-enterostomy, pyloroplasty, and pylorectomy.

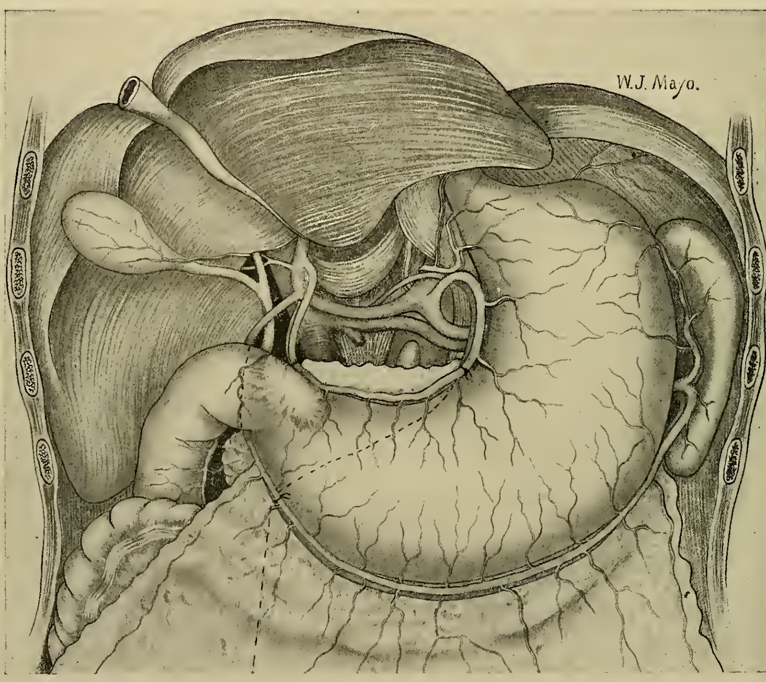
In **gastrotomy** the stomach is opened anteriorly to remove foreign bodies, to treat a stricture of the esophagus by retrograde dilatation, or for exploration.

In **gastrostomy** a *gastric fistula* is established in order to feed the patient

when there is a cancerous stricture of the esophagus. The many recent modifications of the technique of gastrostomy have aimed at *preventing leakage* of the stomach contents. This is more or less perfectly secured in Witzel's method by suturing the stomach wall over the tube for 5 cm. or so from the opening, and thus making a long oblique fistula surrounded by the muscle of the stomach wall; in Kader's and Senn's method, by inverting over a tube a small cone of the stomach wall as a valve, etc.

In **gastro-enterostomy** an *anastomosis* is made between a low point in the *stomach* and the upper part of the *jejunum,* 7.5 to 10 cm. (3 to 4 in.) or

Fig. 110

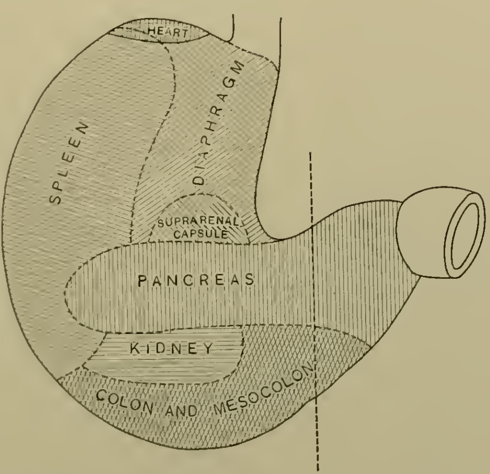


Showing the blood supply of the stomach, the vein indicating the position of the pylorus, the gall-bladder, cystic duct and artery, and the common bile duct. A chronic ulcer is represented at the pylorus and the dotted lines indicate the incisions for its removal. The small omentum has been removed. (Mayo.)

less, from its commencement, when the outlet of the stomach is obstructed and in cases of chronic gastric hemorrhage and intractable pain from ulcer. Though formerly done through the *anterior stomach wall,* it is now most often done through the *posterior wall.* If the anastomosis occupies the *most dependent position* it was thought to make little difference whether the anterior or posterior method is used. But the posterior method has the great advantage of allowing a short loop of 7.5 cm. (3 in.) of the jejunum to be used, the so-called "no-loop" method. The loop is

now thought responsible for the chronic biliary regurgitation and vomiting which occasionally complicates the after-course in these cases, and the anterior method requires a loop of 40 to 50 cm. (16 to 20 in.). Also the straight drop of the bowel from the anastomosis gives protection against secondary jejunal ulcer by the constant presence of the alkaline secretions (Mayo). The *posterior wall is reached* through an opening in the avascular area of the transverse mesocolon. This area lies to the left of the peritoneal band which passes to the commencement of the jejunum from the transverse mesocolon. This band arises from the latter close to the left of a branch of the middle colic artery which comes forward on the right of the duodenojejunal junction. The clamp and suture method is the one now most generally employed. When done for non-malignant conditions the good results are permanent.

Fig. 111



Posterior relations of the stomach. (Testut.)

Pyloroplasty is employed in some cases of pyloric stenosis, and the pyloric opening is enlarged by suturing a longitudinal incision in a transverse direction. In gastroduodenostomy (Finney's operation) a horseshoe-shaped opening in the pylorus and duodenum is sutured so as to make a large opening, in place of a pyloroplasty.

In **pylorectomy** or **gastrectomy,** first employed by Billroth, a large part or the whole of the stomach is removed for gastric cancer and occasionally for ulcer. Owing to the course of the lymph circulation nearly the entire lesser curvature is removed, up to the point where the coronary artery meets it. From here the line of section of the stomach, in pyloric carcinoma, is downward and to the right, so that less of the greater curvature is removed. The object of this is to remove the diseased lymphatics, as well as the newgrowth, in cases where a cancer of the pyloric end of the stomach is removable. The large opening left after resection of the tumor is closed and a gastro-enterostomy added.

How is the Stomach Held in Position?—The stomach is *attached only* at the cardia; the pylorus is fastened to the posterior abdominal wall through its connection with the duodenum. The stomach is also *supported by* the gastrophrenic ligament from the diaphragm, to the left of the esophagus, and by the lesser omentum from the transverse fissure of the liver. The thickened right border of this omentum extends onto the first part of the duodenum as the hepatoduodenal ligament and helps to support the pylorus. The cardia and pylorus are the most fixed points, and the lesser curvature, attached at either end to these fixed points, cannot change its relative position to any extent, hence it is the more fixed border of the stomach. It moves slightly with respiration. In the gradual distention of the stomach the fundus ascends upward and backward into the left cupola of the diaphragm, and the lower part of the stomach, as it descends, is pressed forward by the direction of the "stomach bed" or floor and the relation of the surrounding structures. This brings the greater curvature upward and forward without any distinct rotation of the organ on its long axis. When full the stomach rests below upon the transverse colon and mesocolon, so that the latter and the hepatocolic and phrenocolic ligaments, which help to support the colon, assist in supporting the stomach. The stomach is not supported by intra-abdominal pressure.

The stomach is also *connected with other structures.* At the great curvature the peritoneum covering the front and back surfaces of the stomach meet and pass down as the great omentum. This is the original mesentery of the stomach. Its left extremity, the gastrosplenic omentum, connects the stomach with the *spleen* and inferiorly the portion known as the gastrocolic ligament connects the stomach with the *transverse colon.*

Other Relations of the Stomach.—The *posterior surface* of the stomach *rests* in great part on the transverse mesocolon, above this on the pancreas, with the splenic vessels along its upper border, more to the left on the splenic flexure of the colon, the upper half of the left kidney, the entire left suprarenal capsule, and the anterior surface of the spleen. This is called the "stomach bed," and it slopes from above downward and forward. In addition, the crura of the diaphragm, the aorta, the vena cava inferior, the fourth portion of the duodenum, and the solar plexus also lie behind the stomach. Between the pancreas, kidney, and suprarenal capsule behind, and the stomach in front lies the *lesser peritoneal sac. Perforating ulcers* of the posterior wall of the stomach may open into this sac or, after adhesion, into one of the viscera named as lying behind it, causing perhaps an abscess of the organ so invaded. Cases are recorded where such ulcers have given rise to ulceration of the splenic artery, causing a fatal hemorrhage into the stomach. On cross-section of the abdomen the stomach is seen to lie between the liver and the spleen, so that it may be displaced by enlargements of either of these organs.

Layers of the Stomach Wall.—*Peritoneum* covers the entire stomach except for a narrow strip along the lesser and greater curvatures, where the anterior and posterior layers are continuous with the small and great

omenta respectively, and where the vascular trunks run. This serous layer is closely bound by a scanty subserous tissue to the thick muscular layer. Only in a distended stomach does the peritoneum retract somewhat on incision. The *muscular tissue* is quite thick, so that in suturing there is more for the sutures to hold to and less danger of the needle penetrating all the coats than in intestinal suture. Owing to the difference in direction of the fibers of the three layers, and of the line of their retraction on division, *gastric wounds* are *ragged* and not likely to gape. If small, they may be quite effectually plugged by the protrusion of the mucous membrane, which is permitted by the looseness of the *submucous tissue*. The latter also allows the non-elastic *mucous membrane* in an actively contracted stomach to form prominent longitudinal folds, more marked toward the pyloric end and along the great curvature, which greatly reduce its lumen. The folds may partly or wholly disappear when the stomach is relaxed. There is a *zigzag line* encircling the cardiac orifice on its inner surface opposite the tenth thoracic vertebra, where the thick columnar epithelium of the gastric mucosa joins the thinner squamous epithelium of the esophageal mucosa.

Vessels.—**The arteries**, derived from the gastric, hepatic, and splenic branches of the celiac axis, run along both curvatures of the stomach and from both ends, anastomosing where they meet. Branches pass from these trunk vessels, at right angles to the trunks and to the axis of the stomach, over both surfaces where they anastomose on meeting. The **veins** take the same course. Hence an *incision* parallel with and near the curvatures divides many of these branches where they are largest, and considerable hemorrhage results. Near the curvatures incisions at right angles to them (*i. e.*, parallel with the vessels) cause less bleeding, while midway between the curvatures incisions parallel with them occasion but little hemorrhage. As the blood supply is from three sources, and the anastomoses are numerous, the nutrition of the wound edges, even after extensive resections is well maintained, as a rule. If the larger trunk vessels are concerned in a gastric ulcer and become adherent to the stomach wall and finally eroded, serious hemorrhage into the stomach may result. The *veins empty into* the *portal vein* either directly or through the splenic and superior mesenteric. Hence the varicose gastric veins and the *congestion of the stomach* with hemorrhage into it, in cirrhosis of the liver, or cardiac disease accompanied by portal obstruction. At the cardiac orifice the gastric veins anastomose with the esophageal veins which empty into the superior cava.

The Lymphatics of the Stomach.—There are three distinct lymphatic territories of the stomach: (1) Along the lesser curvature and the two-thirds of both surfaces adjacent to it; (2) the remaining surface on either side of the greater curvature at the pyloric end; (3) a similar strip along the vertical portion of this curvature *i. e.*, the fundus. From (1) lymph vessels pass to nodes along the lesser curvature, grouped principally near the spot where the coronary vessels approach this border; from (2) they pass to 3 to 6 nodes between the layers of the great omentum, beneath the pyloric portion of the stomach, and 2 or 3 nodes behind the pylorus and

in front of the pancreas; from (3) they pass to nodes along the splenic artery. Districts 1 and 2 are the most important. They drain the pyloric end where cancer occurs. The position of glands of district 1 direct the course of the incision in gastrectomy (p. 329).

Nerves.—The *anterior and posterior gastric plexuses,* formed by the left and right pneumogastric nerves respectively, together with sympathetic branches from the solar plexus, *lie near the lesser curvature* at its cardiac end. The abundant nerve supply accounts for the severe pain of ulcer and the collapse caused by injury. When the pylorus is adherent and is much dragged upon during operation severe shock may be observed, due to the disturbance of the large sympathetic nerves and plexuses behind it. The relation of the sympathetic nerves of the stomach with the seventh to ninth spinal nerves accounts for the epigastric tenderness and the reflected left shoulder-blade pain in gastric ulcer, etc. It will be noticed that the plexuses are along and near the lesser curvature, especially at its cardiac end, explaining the reflex palpitation of the heart, faintness, or asthma which may occur after going to bed with the stomach full of an undigested meal, which then presses against the lesser curvature and irritates the nerves. After vomiting the attack subsides. Irritation of the gastric pneumogastric filaments may be misinterpreted by the brain as an irritation of the pulmonary fibers and give rise to a "stomach cough." Irritation of the pneumogastric filaments in the neck, brain, or stomach (from disease, concussion, or in a sea voyage) may cause vomiting.

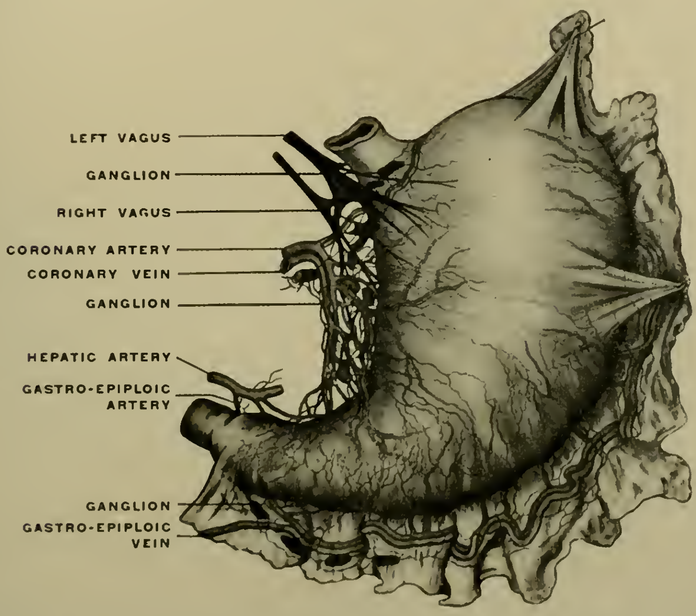
Congenital Malformations.—Congenital malformations of the stomach are rare. It may be displaced in cases of transposition of the viscera and of congenital deficiencies of the diaphragm or anterior body wall. Complete congenital atresia of the pylorus is very rare; stenosis of the pylorus is more common. In certain rare cases an *hourglass stomach* is probably of congenital origin, in most cases it is due to cicatricial contraction following ulcer or corrosive poison, and it is very much more common in females than in males.

The **pathological conditions** affecting the anatomy of the stomach are chiefly *ulcer and cancer.* **Ulcer** occurs along the *lesser curvature* in 36 per cent.; on the posterior wall in 25 per cent.; at the pylorus in 15.6 per cent.[1] Among chronic ulcers 75 per cent. are in the pyloric region. The acute round ulcer is more evenly distributed. Ulceration of the distal 18 mm. ($\frac{3}{4}$ in.) (the canal of Jonnesco) is not common. Occurring so often on the lesser curvature, *pain* does not come on so immediately after eating a meal as in case of gastric catarrh, where the great curvature is chiefly involved, for pain occurs only when the food is in contact with the ulcer, hence vomiting brings relief. Chronic gastric ulcer is usually single, but in perhaps half the cases of acute ulcer more than one is present. Chronic ulcer is not infrequently saddle-shaped, involving both surfaces and the curvature between them. Acute ulcer occurs more commonly in women, chronic ulcer in men. Perforation of the

[1] Fenwick's analysis of 1015 cases.

stomach is liable to occur in both forms, but more frequently in acute ulcer. If adhesions take place, the perforation may be closed or a circumscribed abscess formed, otherwise a general peritonitis ensues. The *cicatricial contraction* following an ulcer at the pylorus narrows the orifice and causes *pyloric obstruction.* This causes at first an hypertrophy of the stomach, to overcome the obstruction, but later on this gives place to dilatation and its sequelæ. An *hourglass stomach* may result from the cicatricial contraction if the ulcer occurs in the body of the stomach. *Adhesions* to contiguous viscera may cause violent gastralgia owing to the traction on the stomach. **Cancer** of the stomach affects the pylorus in 60 or more per cent. of the cases, where sooner

FIG. 112



Showing anatomy of the stomach, with especial reference to the distribution of the lymphatics. (Mayo, after Cunéo.)

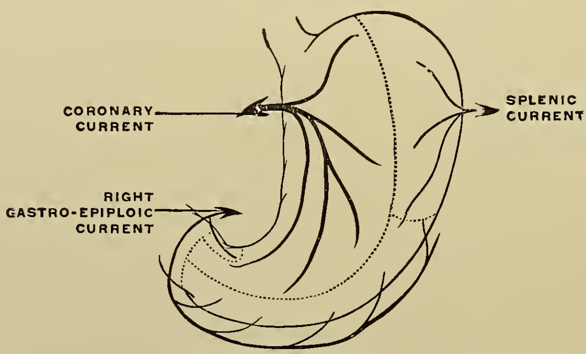
or later it usually obstructs the outlet with the resulting sequelæ. In a considerable proportion of cases the cancer has its origin in a chronic ulcer. *Lymphatic infection* is said to be less frequent and less rapid than in cancer elsewhere, occurring in only about 50 per cent. of cases (Sutton). Palpation of the tumor in its early stages is unsatisfactory on account of its depth and the liver and other structures which overlie it.

In *diaphragmatic hernia* I have seen the stomach in the left pleural cavity, and many such cases are recorded. A part of the stomach may occasionally be found in an *umbilical hernia.* Exceptionally the stomach may be *ruptured* by a contusion. There is more danger of this when the stomach is full, and hence in closer contact with the abdominal wall.

Vomiting is *effected* by the abdominal muscles compressing the stomach against the liver and diaphragm. The latter is depressed to its lowest level by a full inspiration and fixed by the closure of the glottis, so that a patient with an opening in the trachea cannot vomit. As vomiting is naturally easier with a full stomach, plenty of warm water should be given with an emetic. *Eructation* is accomplished by the muscular action of the stomach alone.

The Small Intestine.—The small intestine, extending between the pyloric and ileocecal valves, *averages in length* in the adult, independently of height, weight, or age, 675 cm. (22½ ft.) in the male and 700 cm. (23⅓ ft.) in the female (Treves). In the infant at birth it averages 285 cm. (9½ ft.). The *diameter* and the thickness and vascularity of the wall decrease from its upper to its lower end, the former from 5 to 3.5 cm. (2 to 1½ in.) in the duodenum to 3 cm. (1¼ in.) in the lower ileum.

Fig. 113



Lymphatic areas of the stomach. (Cunéo.)

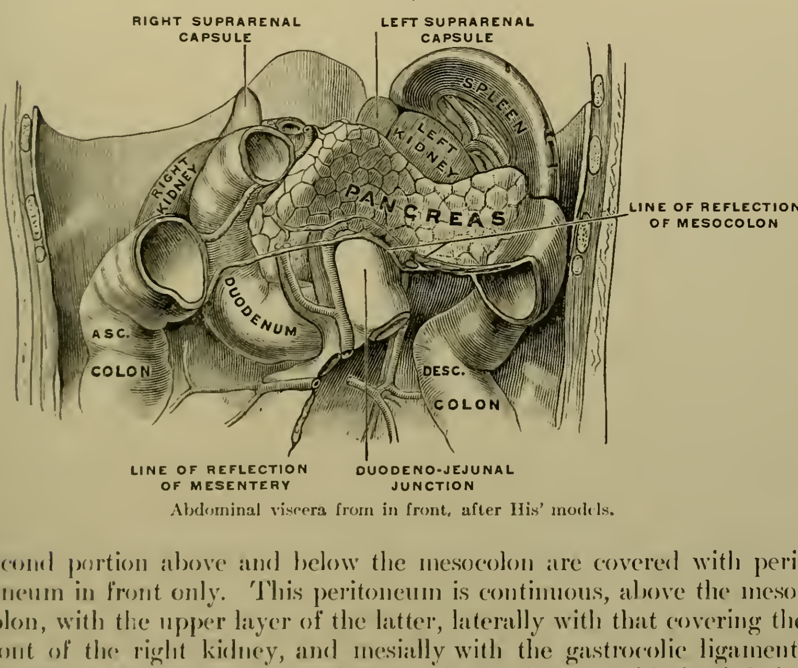
The Duodenum (Figs. 109, 110, 115, 121 to 123, and 126).—The duodenum or first portion is the only part having a fixed position or extent, 25 to 30 cm. (10 to 12 in.). It *lies* in great part retroperitoneally. In *shape* it forms a kind of spiral, within which is the head of the pancreas. Its natural *division* into three or four parts is useful in studying its relations.

The **first part** (or superior longitudinal portion) is about 5 cm. (2 in.) long, and is the most *movable* part on account of its peritoneal relations. Its entire anterior surface and the first 2.5 cm. (1 in.) or so of its posterior surface, next to the pylorus, are covered by peritoneum continuous with that of the stomach and of the right end of the lesser omentum, known as the *ligamentum hepatoduodenale*. Thus this portion of the duodenum is allowed to follow the movements of the stomach, and so avoid undue traction. The *direction* of this segment is nearly horizontal and varies with the fulness of the stomach. When the stomach is distended and the pylorus is pushed over to the right it passes nearly directly backward. When the stomach is empty its course is nearly transverse from left to right, with only a slight inclination backward, and between these

extremes its direction varies according to the condition of the stomach. Its *distal end* is fixed at the level of the first lumbar vertebra, under the right lobe of the liver, or the neck of the gall-bladder, so that it is found stained by bile postmortem. It forms the lower boundary of the foramen of Winslow. The common bile duct, the vena portæ, and the gastro-duodenal artery pass *behind it;* the head of the pancreas lies *below it.*

Behind the neck of the gall-bladder it bends downward into the **second part,** which *descends* for nearly 7.5 cm. (3 in.) to the right of the first, second, and third lumbar vertebræ and in front of the vena cava, the renal vessels, and the inner edge of the right kidney. These relations are to be borne in mind in operations on the right kidney. About its middle it is crossed in front by the attachment of the two layers of the transverse mesocolon, between which it is entirely bare of peritoneum and nearly in contact with the right end of the transverse colon. The parts of the

Fig. 114



Abdominal viscera from in front, after His' models.

second portion above and below the mesocolon are covered with peritoneum in front only. This peritoneum is continuous, above the mesocolon, with the upper layer of the latter, laterally with that covering the front of the right kidney, and mesially with the gastrocolic ligament. Below the mesocolon the peritoneum is continuous with its inferior layer.

The *supracolic portion* is in *contact with* the under surface of the right lobe of the liver, on which it forms an impression (impressio duodenalis) to the right of the neck of the gall-bladder. The relation of the supracolic portion of the duodenum to the gall-bladder, in front of it, explains how gallstones may ulcerate through the latter into the former, and how the two may be anastomosed (cholecystenterostomy) to form an outlet for the bile in irremovable obstruction of the common duct. To the left of it lies the head of the pancreas, which sometimes overlaps it in front, and

between the two are the pancreaticoduodenal artery in front, and the common bile duct behind. It is bound to parts behind it by areolar tissue, which renders easy its separation from them and allows of some change in position of the duodenum in the transverse direction. Thus by incising the peritoneum on the right side of the supracolic portion we may raise up this part and displace it to the left, so as to reach the lower end of the common bile duct, or mobilize it, so as to allow the easy performance of gastroduodenostomy (Finney, Kocher). Downward shifting is entirely prevented by the fixation of the first part by the hepatoduodenal ligament, and in this way any traction on the pancreatic and common bile ducts and the resulting functional disturbances are prevented.

The supracolic portion and the first part of the duodenum are *exposed* between the liver and the transverse colon by pulling the former up and the latter down, retracting the stomach to the left, and following the pylorus to the right. Sometimes, on account of a high position of the transverse colon and mesocolon, but little of the duodenum is to be found above them. The *common bile duct,* usually in common with the pancreatic duct, enters the duodenum at the end of a papilla on the inner and dorsal aspect of the second portion, about 7.5 to 10 cm. (3 to 4 in.) from the pylorus. On the *interior of the duodenum,* at the junction of the first and second portions, is a *crescentic fold* of mucous membrane, on the inner and posterior aspect. According to Brewer, this fold is permanent, is made prominent by pulling the bend upward, averages 47 mm. (1.9 in.) from the pyloric valve and 35 mm. (1.4 in.) from the papilla, and may be useful in finding the latter.

The second portion of the duodenum is sometimes opened in front to remove a stone impacted in the ampulla of Vater (see p. 372). Ochsner has called attention to a marked thickening of the circular fibers 2 to 4 cm. below the papilla, whose contraction narrows this portion and may cause a distention of the parts above and the regurgitation of bile into the stomach. Physiologically it may provide for the thorough mixing of the chyme with the biliary and pancreatic secretions.

Ulcer of the duodenum was formerly thought to be uncommon, but among 200 cases operated upon, 98 were of the duodenum, 87 of the stomach, and 15 of both (Mayo). They occur mainly in the first 4 cm. ($1\frac{1}{2}$ in.) of the duodenum and altogether above the bile papilla, *i. e.,* in the area where the contents are acid. In most cases they are on the anterior wall and extend up to or near the pylorus. They occur more often in males, in the ratio of 3 to 1. Perforation is not infrequent, and is not rare without previous symptoms. Severe hemorrhage may complicate these cases. Cicatrization may result in stricture. *Brunner's glands,* which are said to be the seat of the uncommon ulceration in cases of burns, are mostly in the upper part of the duodenum, and perforation of such ulcers is apt to be intraperitoneal.

The **third or transverse portion** of the duodenum, nearly 12.5 cm. (5 in.) long, *extends* from the right side of the third lumbar vertebra across the latter to the left of the third or second lumbar vertebra, *crossing* in front

of the crura of the diaphragm and the great vessels. It crosses the vena cava where the left renal vein enters it. Though this is considered the normal arrangement, exceptions are frequent, and according to Dwight the third portion does not cross the aorta except in 20 per cent. of cases. It is the most fixed part of the duodenum, and is only covered in front by peritoneum, continuous with the lower layer of the mesocolon.

Where the superior mesenteric vessels, which emerge between it and the pancreas, and the root of the mesentery cross the front of the duodenum, the latter is free of peritoneum. At this point an obstruction of the duodenum may occur from the pressure upon it by the root of the mesentery when the latter is pulled upon by the weight of the intestines hanging in the pelvis, especially when they are pushed down by a dilated stomach. Such an "arteriomesenteric obstruction" is a primary or contributing cause of acute dilatation of the stomach in over 27 per cent. of the cases. In such cases relief follows lying on the belly or in the knee-chest position (Conner). I have verified this in a recent case.

The **fourth, or ascending part,** about 2.5 cm. (1 in.) long, *ascends* in front of the left crus of the diaphragm to the second or first lumbar vertebra, so that the end and the beginning of the duodenum are nearly at the same level, and both are held firmly suspended. According to Dwight it is in front of or just crosses to the left of the aorta in most cases, and may be wholly on the right side (in 1 case in 9). It ends by turning forward into the jejunum at the duodenojejunal angle. This part is firmly held in place by a band of fibrous tissue, containing some muscle fibers, that descends from the left crus of the diaphragm and is continued into the mesentery between its folds, the *suspensory muscle of the duodenum and mesentery* (Lockwood). (See Mesentery.) In consequence of the latter, the duodenojejunal bend remains unaltered in position, no matter how much the stomach and intestines are displaced. *Peritoneum* covers the fourth portion in front and partly at the sides.

In about 50 to 75 per cent. of the cases examined, a *fold of peritoneum* is to be found passing from the anterior surface of this portion of the duodenum to the parietal peritoneum on its left side. This fold is the anterior boundary of a *triangular pouch* which lies to the left of the gut, and is known as the inferior **fossa duodenojejunalis, or Treitz' fossa.** Its *apex* is below the bend between the third and fourth portions, the *opening* lies superiorly and admits the tip of the finger and sometimes of the thumb. The fold is the remains of the fetal "*duodenal fold.*" The duodenojejunal junction actually occupies the fossa. The fossa is exposed by retracting the transverse colon upward and the upper end of the jejunum to the right. It is important as being the starting point of a *retroperitoneal hernia.* This is small at first, but, gradually dilating the fossa, the latter may eventually contain nearly the entire small intestine, as in the case reported by Sir Astley Cooper and in several others observed since. Three or four other fossæ are described at the duodenojejunal junction.

All parts of the duodenum have been *ruptured* by violence, though

this is not common. The duodenum may be *wounded* from behind without opening the peritoneum, owing to its large non-peritoneal surface. Only the first portion has ever been found in a hernia. It will be noticed that the *shape* of the duodenum is not unlike that of a *trap* used in plumbing, and it is not unlikely that it acts as such, preventing the regurgitation of intestinal gas into the stomach.

The Jejunum.—The **jejunum** (*jejunus,* empty, *i. e.*, the condition in which it is usually found after death) and the **ileum** (εἴλειν—to twist, *i. e.*, the curved or twisted intestine) lie for the most part inside of the more fixed large intestine. Their *attachment* to the posterior abdominal wall *by the mesentery* allows of such free motion of the coils on one another that they are well adapted to withstand the effects of pressure and contusion, an important fact, for of all viscera they are *most exposed to injury.*

In consequence of their freedom of motion, a definite and *constant position* of the different coils is *not possible.* Yet in general they are disposed in an irregularly curved manner from left to right, and the jejunum is largely above the ileum and occupies the umbilical and left lumbar and iliac regions, while the ileum is found in the pelvis, the hypogastrium, and the right side. They lie mostly within the frame formed by the ascending, transverse, and descending colon, *i. e.*, mostly in the umbilical and hypogastric regions, but they overlap the colon in the lumbar and iliac regions unless it is distended. For directions for following the jejunum and ileum to either end see Mesentery (p. 323). To find the commencement of the jejunum (as for gastro-enterostomy) the omentum and transverse colon should be lifted up and the small intestine pressed to the right. Then following the mesocolon back to its attachment in the median line, the jejunum is felt or seen, usually just to the left of the median line. In the reclining position the first loop of jejunum naturally sinks toward the left, as far as its mesentery allows, but in the upright and other positions this portion probably has no fixed direction.

Some coils of the jejunum, corresponding to the longest part of the mesentery, are found *in the pelvis.* The terminal coils of the ileum just proximal to the ileocecal valve are also, as a rule, found in the pelvis. The *fetal pelvis* contains no small intestine, and the amount present in the adult pelvis depends upon the distention of the bladder, rectum, and sigmoid flexure, and the size of the female pelvic organs. The coils of the ileum and jejunum occupying the pelvis are of interest, as they are apt to become involved and adherent in pelvic peritonitis, and the *ileum,* or lowest part, is that most frequently found in inguinal or femoral *hernia,* though the jejunum, from its position in the left iliac fossa, would also be likely to be present in left inguinal or femoral hernia. Hence, theoretically, the symptoms of obstruction would be likely to be more acute in a strangulated hernia on the left side than in one on the right side, because the jejunum is more likely to be present in the former. In this connection we may say that *intestinal obstruction,* or other lesions of the intestine, are more serious the nearer they are to the stomach, and hence are more serious in the jejunum than in the ileum. In obstruction of the jejunum

nutrition is much interfered with, for vomiting commences early and is very frequent, the abdomen is but little distended, the expression becomes quickly pinched and anxious, and the progress of the case is rapid and acute, while similar lesions of the ileum are less acute. The acuteness of the symptoms and the fatality of strangulated umbilical hernia may depend partly upon its liability to contain coils of the upper jejunum.

The ileum, from its position, is more apt to be strangulated by internal bands, holes in the mesentery, etc. The coils of intestine must accommodate themselves each moment to changes in form and position of the peritoneal cavity, depending upon the movements of the diaphragm and abdominal muscles, the filling or emptying of the viscera, the presence of effusions, tumors, etc. Hence the rigid fixity of the abdominal muscles and the absence of diaphragmatic breathing in peritonitis, to diminish the movements of the inflamed peritoneal surfaces. A similar object is sought in the opium or the starvation treatment of peritonitis by decreasing the peristaltic movements of the coils against one another. Abdominal tumors cause a displacement or change of position of the intestines, which varies with the size and position of the tumor, and is useful in the diagnosis of the latter. In like manner the small intestine floats on the fluid in cases of ascites so as to be mostly in front or above, according as the patient is reclining or erect. The upper part of the jejunum and the lower part of the ileum are the most fixed portions, as their mesentery is shorter than elsewhere, and hence they are most liable to rupture from injury. But the jejunum, 40 to 50 cm. (16 to 20 in.) from its upper end, is freely enough movable to allow it to be drawn up without tension over the transverse colon and fastened to the stomach in anterior gastro-enterostomy.

Though the upper two-fifths of the small intestine below the duodenum is called the jejunum, and the lower three-fifths the ileum, there is no definite point where one may be said to end and the other to begin. It is often difficult to tell to which part a given coil belongs when it is exposed by operation or accident, especially if the size or appearance is altered by disease. But between the upper end of the jejunum and the lower end of the ileum there is considerable difference. The diameter of the former is 3 to 3.5 cm. ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.); of the latter, 2.5 to 3 cm. (1 to $1\frac{1}{4}$ in.). The walls of the former are more vascular and thicker, owing largely to the valvulæ conniventes, which are large and numerous, while they are scanty in the lower part of the jejunum and nearly wanting in the upper part of the ileum. If the intestine is opened and presents a large number of well-developed valvulæ conniventes, we may infer that the opening is in the upper jejunum, and if few or no valvulæ conniventes, that it is in the lower ileum. These valvulæ are readily felt on palpation in the upper part (jejunum), not in the lower intestine (ileum). If we look through the empty gut toward a light, the lines of the valvulæ conniventes can be well seen.

Monks has described a method of identifying the position of a given loop of small intestines by the arrangement of the vessels in the mesentery. The branches of the superior mesenteric artery in the mesentery

unite with one another to form a series of loops from which the straight vasa recta run to the bowel. This holds for the first 90 cm. (3 ft.). Then a series of secondary and even tertiary loops appear as we proceed down the intestine, the loops getting nearer and nearer the gut, and the vasa recta becoming shorter, *i. e.*, 3 to 5 cm. above, 1 cm. or less below. In the lower ileum the loops lose their characteristic appearance and the vasa recta become branched. The contents also vary in the two parts of the bowel considered, corresponding to the stage of digestion.

In the persistent vomiting of intestinal obstruction or peritonitis, after the stomach is emptied, the bowel contents are regurgitated by reverse peristalsis and are vomited. The character of the vomit changes from the sour stomach contents to the bitter bile-laden contents of the upper bowel, and finally the matter may become fecal. Fecal or stercoraceous vomiting means vomiting of intestinal contents, though the latter do not really become fecal in odor or character above the lower ileum. The stomach and upper bowel may be nearly or quite free of bacteria. The latter increase in number as we proceed down the intestine.

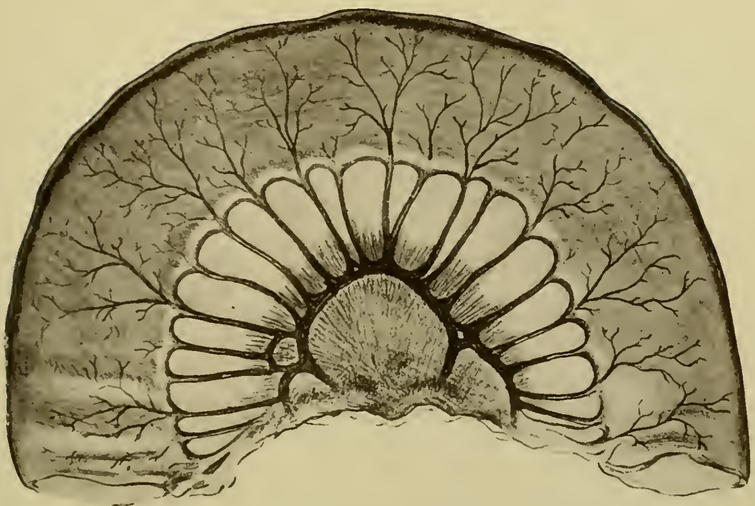
The Layers of the Intestinal Wall.—The **peritoneal coat** is so nearly complete that a wound from without or a perforation from within can scarcely occur without involving it. Between the two layers of the mesentery where they pass onto the bowel there is a strip of the latter averaging 8 mm. ($\frac{5}{16}$ in.) in width uncovered by peritoneum. This area is the usual cause of the occasional leakage after enterorrhaphy, for the essential feature of the operation is that the serous coat of both ends of the divided gut should be brought together at all points. In enterorrhaphy or in the use of the Murphy button, or other aids to intestinal anastomosis, the two layers of the mesentery, where they pass onto the bowel, should be carefully brought closely together by suture so as to complete the circle of the serous coat. Loss of substance of a limited area of the peritoneal coat may occur without serious impairment of the strength or function of the part of the bowel involved, though strong adhesions are likely to occur here.

The inner or circular **muscular coat** is three times as thick as the outer layer of longitudinal fibers, hence a longitudinal *wound* gapes more than a transverse one. Owing to the greater thickness of the longitudinal fibers along the free border of the gut, transverse wounds across this part of the gut gape more than elsewhere. Wounds of the jejunum gape more than those of the ileum, owing to the greater muscular development of the former. *Minute wounds* of the intestine are *closed* by the contraction of the muscular coat so as to prevent extravasation. The bowels have been punctured without ill effects in many places to allow the escape of gas when excessive tympanites exists, and in abdominal operations to facilitate the return of the intestine within the abdomen. At present, however, fewer and larger openings are usually made and afterward sutured. Wounds somewhat larger than punctures are plugged by the protrusion of the loose mucous membrane, which may or may not prevent extravasation. Treves[1] mentions a stab wound with a small puncture of the ileum which remained closed by such a protrusion

[1] Surgical Applied Anatomy.

PLATE XXXIII

FIG. 115



A Loop of Intestine, the Middle of which is Exactly Three Feet from the End of the Duodenum. (Monks.)

The gut is of large size. The mesenteric loops are primary, and the vasa recta large, long, and regular in distribution. The translucent spaces (lunettes) between the vessels are extensive. Below, the mesentery is streaked with fat. The veins, which had a distribution similar to the arteries, are for simplicity omitted from this and from the subsequent drawing (The subject from which the specimen was taken was a male aged forty years, with rather less than the usual amount of fat. The entire length of the intestine was twenty-three feet.

FIG. 116

A Loop of Intestine at Twelve Feet. (Monks.)

The vessels are smaller. The primary loops are lost in the fat, but secondary and even tertiary loops are visible. The vasa recta are shorter, more irregular, and branching.

of mucous membrane, aided by recent lymph, for four days when fatal symptoms suddenly occurred, and it was found postmortem that an intestinal worm (Ascaris lumbricoides) had escaped through the wound and led the way for extravasation.

In **larger wounds** the size of the opening is much *reduced* by muscular contraction. Thus, Gross found in longitudinal wounds a reduction in length of one-half. The mucous membrane is also much everted by reason of the muscular contraction, and this is to be remembered in intestinal suture, for it must be inverted in order to bring the edges of the serous membrane together, and thereby secure firm healing of the wound, for mucous membrane does not unite with mucous membrane on its epithelial surface.

In order to secure the healing of intestinal wounds the serous layers are somewhat inverted by *Lembert, Halstead, Cushing, or similar sutures.* The suture catches up the serous, muscular, and submucous layers external to the line of the wound, so that the suture punctures do not reach the latter, but leave a narrow free strip on either side of it. Thus when the sutures are tightened the edges are inverted and the strips of the peritoneal coat between them and the lines of suture on each side are brought in contact.

The worm-like **peristaltic movements** of the intestine are the result of the consecutive contraction of successive portions of the muscular coat. This may be seen through thin abdominal walls and heard on auscultation where the latter are thicker. It is increased when there is a mechanical obstruction, and diminished or wanting when there is paralytic (dynamic) obstruction. Abnormally this action may be reversed, as in intestinal obstruction, and force the contents toward the stomach instead of toward the colon, and thus produce fecal vomiting. "Colic" is due to an irregular or spasmodic contraction of the muscular wall, and is analogous to a cramp in the leg, etc. It is not associated with abdominal tenderness or rigidity.

The **caliber** of the intestine varies with the contraction of its muscular wall. When empty the bowel becomes contracted. It may be distended by accumulated fecal matter or by gas, so as to be larger than the large intestine. In septic peritonitis and in some other septic conditions the muscular wall in time becomes paralyzed by septic poisoning. Peristalsis, therefore, ceases and obstruction follows, while the stagnant fecal matter develops gas which distends the bowel. From the peritoneal coat of sheep comes the "*catgut*" of commerce, so much used in surgery.

The **mucous membrane** is *loosely connected* with the layers on which it rests, so as to permit it to move freely over them. This allows it to become everted, so as to plug a small wound, and to become prolapsed in some cases of artificial anus, thus preventing spontaneous closure.

Peyer's patches, occurring principally in the ileum and especially in its lower two-thirds, are placed lengthwise of the intestine on the side opposite the mesenteric attachment, and hence are best exposed by opening the gut along the attachment of the mesentery. They are the seat of typhoid as well as tuberculous ulcers, the former of which usually

extend longitudinally in the axis of the patch, the latter transversely in the direction of the encircling bloodvessels. In one case of perforating typhoid ulcer, on which the writer operated, the long axis of the ulcer was transverse. In the great majority of cases a typhoid perforation occurs in the lower two feet of the ileum.

The vessels of the small intestines *enter or emerge* from the bowel along the narrow strip, uncovered by peritoneum, at the mesenteric attachment. The **arteries** run transversely from either side, thus encircling the gut. This arrangement of the arteries sometimes enables us to distinguish the intestines from other structures in case of doubt.

The large anastomosing branches, which lie between the two layers of the mesentery, are liable to be injured in stab or gunshot wounds and to give rise to serious hemorrhage. The vessels of the mesentery may be occluded by thrombosis or embolism. In spite of the apparently free anastomoses the collateral circulation is very rarely established. Whether the artery, the vein, or both are occluded, gangrene results and may involve 2.5 to 5 cm. (1 to 2 in.) or many feet of the gut.

The **veins** accompany the arteries singly, and flow through the superior mesenteric into the portal vein. Hence they are affected by portal congestion in some conditions of the liver, and septic infection may be carried by them to the latter from the intestine, sometimes producing pylephlebitis, or abscess of the liver.

The **lymphatics** form two sets, as in the stomach, a deep set in the mucous membrane, and a superficial set in the muscular layer. In the mesentery they are known as chyle vessels, on account of the milky fluid they contain. In emergency operations, performed not long after a meal, these vessels show very plainly as fine white streaks. They enter numerous (130 to 150, Quain) lymph nodes between the folds of the mesentery, at and near its parietal attachment, which are subject to enlargement in lesions of the intestine like tuberculosis, typhoid fever, dysentery, cancer, etc. In case of enlargement of these nodes the lesion should be sought in the intestine.

The **nerves** come from the celiac and superior mesenteric plexuses of the sympathetic, with some fibers from the right pneumogastric. For the connection between the nerves of the intestine and those of the abdominal wall, see the latter (p. 281).

Meckel's diverticulum, a persistent proximal portion of the vitelline duct, is a blind glovefinger-like pouch having the same layers as the ileum and a lumen continuous with it. It arises from the free margin of the ileum from 30 to 90 cm. (1 to 3 ft.) from its lower end. It averages 5 to 7.5 cm. (2 to 3 in.) in length, but may be much larger, and ends in a free cylindrical, conical, or globular extremity, or in a fibrous band which may connect it with the umbilicus, as in fetal life, or with other parts. It can *cause obstruction*, when its end is adherent, by forming a bridge beneath which a loop of bowel may be strangulated, or by pulling on the ileum at its attachment so as to kink the latter. It occurs once in about 50 cases, has been found in external herniæ, and may give rise to a condition resembling appendicitis.

In operations upon the intestines, or in penetrating abdominal wounds which may involve them, it is to be remembered that they are separated in great part from the anterior abdominal wall by the great omentum. As the omentum is the only thing that intervenes between the intestines and the abdominal wall, the *intestines* are much *exposed to contusions* by blows, the effects of which are intensified if received unawares, when the belly wall is relaxed, or if the body cannot bend or yield to the blow. In this way the intestine may be *torn, severed,* or so *bruised* as to slough subsequently and thus lead to a perforative peritonitis. This possibility should be borne in mind in cases of severe abdominal contusions and the prognosis be reserved.

In **bullet or stab wounds,** penetrating and traversing the abdomen, the intestines almost always receive *multiple injuries,* the number of which varies but is generally greater in those wounds whose course is transverse or oblique, because more coils of intestine are thus met with. Occasionally a bullet or knife may pass among the intestines without wounding them. Several such cases are reported where the fact has been demonstrated by operation, but it occurs in less than 2 or 3 per cent. of cases. A bullet whose course passes through near the edge of a piece of intestine makes a larger opening than one passing through the centre, and the wound of entrance and exit may be continuous if they lie along the edge of the gut.

The end of the ileum may slip through the ileocecal valve and become prolapsed into the colon, possibly even to the anus. This is one variety of *intussusception,* and occurs mostly among children (p. 347).

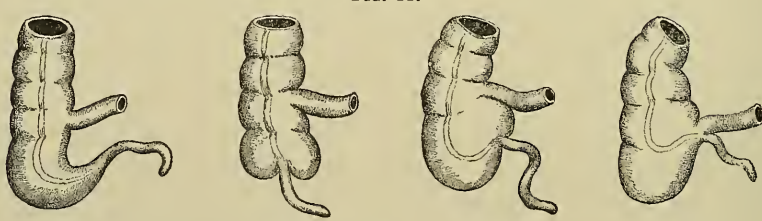
Operations.—*Laparotomy* or *celiotomy* applies simply to the procedure of opening the abdominal cavity for any purpose, and is referred to under the Abdominal Wall. The bowel may be opened (*enterotomy*) to remove an impacted foreign body, in which case it is sutured immediately; or to make an *artificial anus* above an obstruction, after the intestine is sutured into the wound, in which case a low point in the ileum (ileostomy) should be selected if possible. The permanent opening of the bowel below an obstruction and its suture into the wound for the purpose of feeding the patient (*enterostomy*) is usually done in the upper jejunum (*jejunostomy*), so that the food may pass through the greatest possible length of intestine, but the operation is not very popular. In *enterectomy* a portion of the bowel is cut out or *resected* for gangrene, tumors, stricture, multiple injuries from bullet or stab wounds, and many other causes. In a successful case of closure of sixteen bullet wounds of the small intestine, reported by the writer, 7.5 or 10 cm. (3 or 4 in.) of the gut was resected, as there were four holes within 5 cm. (2 in.), the closure of which would have caused a stricture or kinking of the bowel. The successful resection of 330 cm. (11 ft.) (Ruggi) of the intestine has been reported, and many cases where more than one meter has been resected.

After resection *intestinal suture* is performed, preferably by the end-to-end suture, or, if it is not possible to bring the ends together without tension, lateral anastomosis may be made after inverting and closing the

divided ends. As a palliative operation lateral anastomosis is often made between the coils above and below a lesion without resection of the diseased parts (intestinal exclusion). The *end-to-end suture* is preferable if feasible, for peristalsis will follow its natural course and there is little or no danger of stricture from contraction of the opening. Various mechanical aids to facilitate both forms of intestinal union and to save time have been devised, among the most perfect of which is the Murphy button. The importance of securing perfect apposition of the opposing peritoneal surfaces throughout, in the suture of intestinal wounds or operations, has been referred to above.

The Large Intestine.—**Ileocecal Region.**—The **cecum** (Fig. 118), or blind head of the colon, is the large cul-de-sac of the colon that lies below the entrance of the ileum. In man and the carnivora it is rudimentary, while in the herbivora and graminivora it is of great size, so that in man it has been called an anatomical protest against vegetarianism. Its *width,* 7.5 cm. (3 in.), is greater than its *length,* 6.5 cm. ($2\frac{1}{2}$ in.) and it is relatively and absolutely larger in the adult.

Fig. 117



Type 1 Type 2 Type 3 Type 4

Schematic table of types 1, 2, 3, and 4 of human ceca.

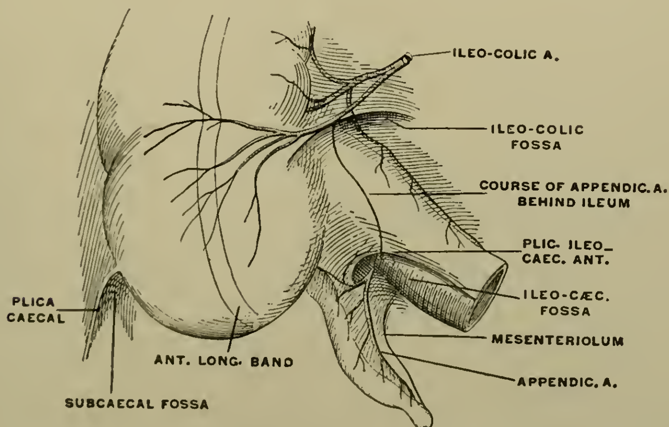
As to **shape,** *four types* may be distinguished, as seen in Fig. 117. (1) The conical *fetal or infantile type* persists in about 2 per cent. of cases among adults. Type 2 occurs in the adult in 3 per cent. of cases. Type 3 is the *common or normal form,* occurring in man in 90 per cent. of cases. In it the right sacculus and the anterior wall have outgrown the left side, so that they form the lower end of the cecum, while the root of the appendix, to which converge the longitudinal bands, has been displaced upward, inward, and backward, to about 16 mm. ($\frac{2}{3}$ in.) below the entrance of the ileum. The *longitudinal bands* are seen to be a uniform and useful guide to the base of the appendix. The anterior band is our best guide to the root of the appendix, for it is the most accessible. Type 4, comprising 4 or 5 per cent. of cases, is an exaggeration of 3, in which the root of the appendix is displaced to the inferior ileocecal angle by the atrophy of the left sacculus.

The cecum is the most *superficial* portion of the large intestine, and hence is most exposed to injury. For the same reason and its mobility it is selected for colostomy on the right side. When full it *occupies* most of the iliac fossa, and is in contact with the anterior abdominal wall, but when empty, as after fasting or when there is obstruction in the small

intestine, it is smaller and covered by coils of the small intestine. Its **normal position** is in the right iliac fossa, on the psoas muscle, above the outer half of Poupart's ligament, with its apex projecting over the inner edge of that muscle and lying a little to the inside of the vertical plane drawn through the middle of Poupart's ligament. It may sometimes lie farther mesially, extending down into the pelvis or toward or even across the median line. Not infrequently it lies more to the right, entirely on the iliacus muscle or with only its apex on the psoas. It is not infrequently *displaced downward* so as to be found *in a right inguinal or* occasionally in a *femoral hernia,* and it has even been found in left-sided herniæ. Such herniæ are provided with a complete peritoneal sac except in very rare cases (see also pp. 294 and 346).

The *fetal cecum* is situated at first within the umbilical region, thence it ascends into the left hypochondrium, from which it passes across into the right hypochondrium and then descends into the right iliac fossa.

Fig. 118



Cecum, appendix, and end of ileum, with the blood supply and the neighboring fossa. Somewhat schematic. (Merkel.)

An interesting and important *variation in the position* is that in which it remains undescended from its fetal position above and to the left of the umbilicus, or lower down near the pelvic brim, the ascending and transverse colon being absent. More often it is *partly descended* and just below the liver or at any point between the liver and its normal position. Accordingly it may even be found in a congenital umbilical hernia. It is not uncommon to find the cecum unusually high on the right side, having been arrested in its descent into the right iliac fossa. The writer has met with such cases in operating for appendicitis where the cecum was above the crest of the ileum. The importance of these irregular positions of the cecum lies in the fact that the appendix is correspondingly shifted in position.

The **direction** of the cecum is not quite vertical, but inclines slightly inward below. If we take as its *upper limit* the lower edge of the ileocolic

junction, the cecum is **completely covered by peritoneum.** The latter, therefore, is first reflected onto the iliac fossa from the ascending colon, so that the subperitoneal areolar tissue of the iliac fossa is never in direct contact with the posterior surface of the cecum, which is free in the peritoneal cavity. The level of this reflection of peritoneum and of the upper end of the cecum varies, but is usually about midway between the level of the anterior superior spine and of the highest point of the iliac crest. Quain, Berry, and others state that in 5 per cent. of cases the peritoneum is reflected just below the upper end of the cecum, leaving the posterior wall of that part connected with the subperitoneal areolar tissue, but they make the cecum reach a higher level, *i. e.*, that of the ileocecal valve. The **mobility** of the cecum depends largely upon the distance between its tip and the reflection of peritoneum posteriorly from the colon, and especially upon the presence of an ascending mesocolon. A mobile cecum may even find its way into a left inguinal or femoral hernia. In some cecal herniæ the peritoneum of the iliac fossa and its reflection onto the lower end of the colon appears to have slid down so as to form part of the posterior wall of the sac.

Foreign bodies that have been swallowed and have passed the pylorus are apt to lodge in the cecum, partly from the effects of gravity. They may ulcerate through the cecal wall and cause perityphilitis. The largest accumulation of feces in cases of *fecal impaction* is often found in the cecum. Hence *stercoral ulcers,* due to the pressure irritation of retained or impacted fecal masses, are more common in the cecum than in any other part of the intestine. The cecum, according to Cobbold, is the seat of the *pin-worm* (Oxyuris vermicularis), but others claim that this is lower down in the colon. *Intestinal concretions* are not uncommonly met with here, but normally the contents of the cecum are fluid. Tuberculous inflammation with great hyperplasia and induration sometimes involves the ileocecal region, producing a large "ileocecal tumor," which may cause obstruction of the bowels or become perforated and set up peritonitis.

In cases of intestinal obstruction the condition of the cecum may assist in diagnosis. If the obstruction be in the colon the cecum will be found greatly distended, while it is normal or collapsed in cases of obstruction of the small intestine. The cecum is capable of enormous *distention,* if gradually effected, and has been observed larger than the full stomach. Flexing the thigh upon the abdomen will empty a slightly distended cecum, if normal in position. The *structure* of the cecum is like that of the colon, the peculiarities of which are described later.

The ileocecal or ileocolic valve guards the entrance of the ileum into the large intestine at the junction of the cecum and colon. It is normally found on the internal and posterior aspect of the large intestine, but rarely, by a rotation of the latter, the ileum may pass behind it and open on its outer side, or it may open more in front when, occasionally, the posterior part of the cecum is more developed than the anterior. The valve consists of *two flaps* formed by the invagination of the ileum into the colon. It is generally found 5 cm. (2 in.) internal to the anterior superior iliac spine and about in the spino-umbilical line, but it is subject to frequent

variations in position. It is *composed* of the mucosa, submucosa, and circular fibers, while the peritoneum and longitudinal fibers pass directly over the angle between the ileum and the large intestine and form no part of the valve. Hence if the two outer layers are divided and traction is made on the ileum the valve is unfolded and pulled up into the ileum, which then presents a funnel-shaped opening into the large bowel. The two flaps project nearly transversely into the lumen of the large intestine, and this projection is continued from either end of the slit-like opening for a short distance around the circumference of the colon as the frena, or *retinacula*, of the valve, similar to a plica of the colon, so that the valve may be said to open on the summit of a plica.

When the cecum and colon are distended the flaps of the valve are pressed together, preventing regurgitation into the ileum. In an ordinary high enema the valve renders impossible the passage of the fluid into the ileum, but if a high pressure is steadily continued the fluid may pass the valve, though probably not before peritoneal lacerations and other damage to the large intestine have occurred. Hence, practically, for diagnostic and therapeutic purposes, the valve is *not permeable to fluids* from below, and the attempt to force fluids past the ileocecal valve from below is unsafe and unjustifiable, unless possibly the injection is given very gradual. Some say that high enemata may pass the valve in a considerable proportion of cases, but in these cases the valve is regarded as imperfect and incompetent from the first. With *air or gases* it is otherwise. Thus, Senn has shown that hydrogen gas inflated into the colon through the rectum, under a pressure of from $1\frac{1}{2}$ to $2\frac{1}{4}$ pounds, *may safely pass the valve,* enter the small intestine, and disclose a wound of the latter, in case of stab or bullet wounds of the abdomen, or be used in the treatment of intussusception. In such cases the incompetency of the valve depends upon gradual lateral and longitudinal distention of the cecum, which mechanically separates the margins of the valve. The same explanation applies to those cases of intestinal obstruction where there is evidence of the return of the contents of the large into the small intestine, though some deny that it occurs. The baneful effect of forced high injections of fluids as compared with that of gases probably depends upon their weight and lack of elasticity. An ordinary high enema causes the emptying of the lower ileum by stimulating its peristalsis so that there is no need to try to force an enema beyond the valve. Narrowing of the valve, either organic or spasmodic, has been suggested as a possible cause of chronic constipation.

Intussusception, the invagination or telescoping of one part of the bowel into the part next below it, generally occurs in this region, and is most common in childhood under the age of ten years. The **ileocecal form** is the commonest, and in it the ileum with the cecum is prolapsed down the colon. The *ileocecal valve* forms the *apex* of the intussusceptum, or prolapsed mass, and may even reach the rectum and present at the anus. Rectal examination should, therefore, always be made in cases where intussusception is suspected. In a rarer form, the **ileocolic**, the ileum is prolapsed through the ileocecal valve into and along the colon. The

valve and cecum retain their positions while the ileum forms the summit of the intussusceptum. A still rarer form is the **colic,** where one part of the colon is invaginated into a part below, but the extent of this is limited by the shortness of the mesentery of the colon. In the *enteric form* the small intestine is invaginated into itself. The intussusceptum stimulates the enclosing intussuscipiens to painful straining to stool (tenesmus), and a discharge of bloody mucus from the anus results. Occasionally the intussusceptum itself is passed, after sloughing.

On section an intussusception is found to consist of *three cylinders* of bowel, two of which belong to the prolapsed part, or intussusceptum, and one to the containing part, or intussuscipiens. A rare form, double intussusception, consists of five cylinders. The *serous surfaces* of the intussusceptum are in contact with one another and are liable to form adhesions. The mesentery is compressed between these surfaces on one side, and this pressure is apt to cause venous congestion, edema, and finally, strangulation and gangrene, with perforation or sloughing of the intussusceptum. In such cases the invaginated bowel may slough off and be passed per anum, and a spontaneous recovery result. Between the intussusceptum and the intussuscipiens the mucous surfaces are in contact.

The appendix vermiformis is a narrow, cylindrical, blind tube, which represents the rudimentary or atrophied lower end of the larger cecum of many other animals. Even in the human fetus it is seen to be merely the narrowed extremity of a capacious cecum. Like other *vestigial parts,* it is prone to *inflammation,* which tends to cause its *obliteration,* a process which evolution would appear to be slowly bringing about.

Its **length** varies between 10 mm. ($\frac{2}{5}$ in.) and 24 cm. ($9\frac{1}{2}$ in.), and *averages* about 8.5 cm. ($3\frac{1}{3}$ in.). It attains its greatest length in early adult life (twenty to forty years, Berry), after which it shrinks somewhat. Its length bears no relation to the size of the cecum. In a few authentic cases it has been reported wanting. When this condition is apparently disclosed at an operation, the fact should be accepted with doubt, for its presence may not be apparent without thorough and careful dissection, when it occupies certain irregular positions. Its **diameter** is about 6 mm. ($\frac{1}{4}$ in.) at the base and 5 mm. ($\frac{1}{5}$ in.) at the apex, but in old age it may become still smaller. The longer the appendix the greater the difficulty, other things being equal, of the egress of a solid or semisolid body from the distal end. With a long narrow process the conditions are favorable to the stagnation of its contents, which predisposes to inflammation.

The *length and the size* of its **lumen** is of more practical interest. The *diameter of the lumen* varies in different parts between that of a fine probe and that of a quill, and the *average,* according to Ferguson, is that of a No. 9 sound of the English scale. A variable point is the *opening into the cecum,* ranging from a mere pinhole to a No. 7 catheter (English scale). It is often guarded by a valve or a prominence of mucous membrane due to an increase of lymphoid tissue beneath it. This is especially so in childhood, and it may decrease or disappear later. The size of the opening here is important, for a small opening admits fluid feces and

prevents or hinders the escape of semisolid material. A valve was described by Gerlach, guarding the appendicocecal orifice and so directed as to cause retention of the appendical contents, but its existence is now doubted.

In about 25 per cent. of cases the *lumen* is partially, less often completely, *obliterated*, commencing with the distal end. It is a *physiological* not a pathological process. Very little (4 per cent.) of this obliteration is found in the first ten years of life, while it is present in over 50 per cent. of cases at sixty years. The obliteration of the lumen at its distal end *shortens it*. The lumen may also be found *stenosed irregularly* here and there, as the result of previous attacks of inflammation (appendicitis), and these stenoses favor recurrence of inflammation by interfering with the proper emptying of the appendix. The presence of the obliteration of its lumen cannot be told by the macroscopic external appearance of the appendix.

The appendix is **held in position** (1) by the attachment of its base to the cecum (see cecum); (2) by a mesentery of its own (mesenteriolum). The base of the appendix, and with it the appendix itself, *varies in position* with that of the cecum. Thus it may be unusually high when the cecum is partly or wholly undescended (see cecum).

The **mesentery of the appendix** (*meso-appendix* or *mesenteriolum*) is derived from the lower or left layer of the mesentery, along a straight line a short distance below the bowel, and not quite parallel with it. It represents a fold of peritoneum raised up by the artery in its passage from the back of the ileum to the appendix. It is *triangular* in shape, with its apex at the base of the appendix and one side attached to the abdominal wall, or the mesentery, the other to the appendix, while the base is free. The mesenteriolum extends to the tip of the appendix in fully one-half of the cases (Monks and Blake), and in the remaining cases about half-way, so that the terminal portion is either wholly covered by peritoneum or it possesses a narrow fringe of peritoneum continuous with the mesentery. The appendical border of the meso-appendix is longer than its parietal border, which partly accounts for the tortuous or coiled position of the appendix, similar to that of the small intestine, and due to the same cause. An ample mesentery affords some security against attacks of appendicitis by avoiding undue angulation of and traction or pressure upon the vessels, which run between its folds.

The appendix is, therefore, an *intraperitoneal organ*, wholly covered by peritoneum except for a narrow strip along the attachment of its mesentery. Hence inflammation of the appendix (*appendicitis*) is an intraperitoneal inflammation, unless walled off by adhesions and plastic exudate. In *exceptional cases* the appendix is in whole or in part *extraperitoneal*. Thus it may lie behind the cecum, adherent to its wall and covered by its peritoneum, or its distal portion only may be extraperitoneal, behind the colon, while its proximal part is intraperitoneal, or vice versa. Probably some of the cases reported as extraperitoneal were really instances of the appendix herniated into and adherent to the ileocecal or subcecal fossæ.

As a result of inflammation the appendix may contract *adhesions* to the visceral or parietal peritoneum with which it is in contact. These adhesions vary from a single delicate one to those completely binding down the entire length of the appendix. The latter condition is not infrequently found in operating for appendicitis. I have found the tip separated from the rest and only connected with it by scar tissue, representing a necrotic area of the tube. In removing an appendix closely adherent to the posterior parietes and directed inward the relation of the ureter and the iliac vessels should be borne in mind. When adherent to the ileum it may even form a constricting band about it, or a bridge may be formed beneath which the small intestine may be strangulated.

It is stated (Clado) that in 1 case in 10 in females there is a process of peritoneum passing from the right ovary to the meso-appendix (*appendiculoövarian ligament*), which *contains* lymphatics and a *small artery* forming an anastomosis between the appendicular and ovarian vessels. It has also been suggested that theoretically this anastomotic circulation would confer a certain immunity against appendicitis, by preventing congestion and avoiding gangrene.

In **position** the appendix, though tortuous, has a *principal direction* from base to apex, and is said to "*point*" this way or that. It may point in any direction, like the needle of a compass or the hands of a watch, and its direction is sometimes indicated by the points of the compass. A great number of observations have been reported as to the direction of the appendix by different observers and with varying results. There are **two main positions** of the appendix: one *upward* behind the cecum, the other *downward* away from the cecum. Both of these main positions may be modified by a *lateral deviation* to the right or left. Thus the appendix may point upward and to the right, and lie to the outside of the cecum and colon, or it may point upward and to the left, lying below the mesentery and the lower end of the ileum. Again, when it points downward it may lie along the pelvic brim or project into the pelvis. The *order of frequency* is (1) retrocecal; (2) pelvic (*i. e.*, down and in); (3) upward and inward; (4) variable. The upturned appendix is probably to be explained by adhesion of its distal end in its descent from its fetal position beneath the liver, the down-turned appendix by the absence of such adhesions. It will be observed from the above that the appendix is *mostly in the right lumbar*, the hypogastric, or the umbilical regions, and more rarely in the right iliac region, though it usually lies in part or wholly in the right iliac fossa.

Its *curved or spiral course* is due to its short mesentery, or, in other words, to its growth between points fixed at an early date. The most fixed point is where the postcecal branch of the ileocolic artery joins it; another fixed point is where the fusion between the non-vascular fold and the posterior vascular fold (meso-appendix) terminates.

The relations of the appendix *to the anterior abdominal wall* are most important for clinical purposes. Both for diagnosis and operation **McBurney's point** is the one most commonly used. This is a point on the line between the anterior superior iliac spine and the umbilicus 6.7 cm.

($2\frac{1}{2}$ in.) from the iliac spine. It lies in the right lumbar region and is a guide not to the position of the appendix itself, which is very mobile, but to its base. Though this varies with the position of the cecum in the great majority of cases it will lie somewhere beneath a circle 5 cm. (2 in.) in diameter, having this point as its centre. Within the same area will be the point of greatest tenderness in appendicitis, but undue value should not be given to the exact point. Clado locates the guiding point lower down on a level with the anterior superior iliac spine at the outer border of the rectus.

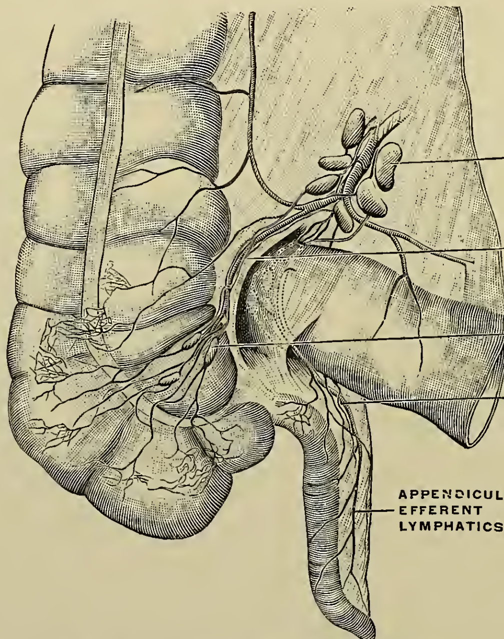
The walls of the appendix present the same layers as those of the cecum and colon. We have already studied the peritoneal covering. The **muscular fibers** are largely replaced by fibrous tissue. The existence of *longitudinal muscle* fibers is seen in the rapid shortening of the appendix after removal, sometimes by one-third of its length. It is spread out uniformly and not arranged in bands as in the cecum and colon. The *circular muscular fibers* are demonstrated by the peristaltic movements of the appendix that are sometimes observed, by cases of so-called appendical colic, and by their retraction so as to expose the mucosa after lengthwise incisions. This layer may form about one-third of the thickness of the appendical wall. The **submucosa** is a thick layer of dense areolar tissue containing many solitary *lymph follicles,* which are more abundant here and in the cecum than elsewhere in the large intestine. They are also more numerous in early life, up to the twentieth or thirtieth year, after which they normally atrophy more or less. Where the lumen is obliterated the mucous glands of the **mucosa** are found to have disappeared, while the other parts remain. The mucosa is also rich in *lymphoid tissue.* Abundance of lymphoid tissue is a marked feature of the appendix, and here, as elsewhere, it is prone to inflammation, especially in early life, when it is in greatest abundance. This corresponds with the known *greater frequency of appendicitis in early life.*

The *distal end* of the appendix is thick and fibrous. The presence of **fecal concretions** in the lumen of the appendix is quite common. They may lead to inflammation and perforation of the appendix, but by no means necessarily cause appendicitis, for we often find them postmortem without sign or history of appendicitis, yet in cases of appendicitis they are present in considerably over 50 per cent. of cases. Although *foreign bodies* may be found in the appendix, they are an infrequent cause of appendicitis, as compared with other causes.

The swelling of the mucosa in inflammation tends to narrow or entirely close the lumen at points already narrowed by stenoses, valves, or duplicatures of mucous membrane, or by twists or kinks in the appendix. As the appendix is contractile but not extensible, it is thus put to great strain to expel its contents. The pressure on its walls, or, more often, the infection and inflammation of them from within, cause venous congestion. This results in swelling, which, unless relieved, goes on to the complete strangulation or obstruction of the vessels, and gangrene results. If a concretion is present as an additional obstructing or compressing agent, local gangrene is even more likely.

Vessels and Nerves.—The appendix is supplied by the **postcecal branch** of the **ileocolic artery.** The main or *distal branch reaches* the appendix by passing along the free border of the meso-appendix, between its folds. The *proximal branch* passes to the root of the appendix. Exceptionally the artery passes directly to the tip of the appendix without branching and then runs back toward its base. In such a case the stasis of its blood current, from pressure, etc., at the tip, would involve the entire appendix in gangrene. Local blood stasis due to inflammatory or mechanical pressure is the cause of local gangrene of the appendix.

Fig. 119



Anterior view of the lymphatics of the cecum and appendix. (Poirier and Charpy.)

The **lymphatics** accompany the artery and enter the ileocecal group of mesenteric nodes, after traversing some small nodes in the meso-appendix just behind or below the ileum or against the cecum, above the root of the appendix. The node or nodes in the meso-appendix may be enlarged or even broken down in appendicitis.

The **nerves** supplying the appendix come from the superior mesenteric plexus, which also supplies the small intestine and the large intestine as far as the splenic flexure. Hence the explanation of the *pain in appendicitis* being commonly referred at first to the abdominal nerve centres in the epigastric or umbilical regions.

Pericecal Fossæ (Figs. 118, 119).—There are a number of peritoneal pouches or fossæ in the ileocecal region which deserve notice because into them the bowel, and especially the appendix, may be herniated.

The upper, or **ileocolic fossa**, lies just above the ileocolic junction, and is *bounded* on the sides by the ileum and the colon, and in front by the fold of peritoneum formed by the passage across the ileocolic angle of a branch of the ileocolic artery. It *opens* downward, but is too high to concern the appendix, and is also less important than the following, because it is *smaller* and *less constant.*

The **ileocecal fossa** is exposed by turning up the cecum and drawing the appendix down and the ileum up. It is *bounded* on the right by the cecum, on the left by the small intestine, in front by the ileocecal "bloodless" fold which passes from the ileum to the meso-appendix, which bounds it behind. It *opens* downward and outward, is almost constant, and is large, admitting two fingers. It is to be remembered that the *appendix* is *often found in this fossa,* which makes it of practical importance. The appendix so placed may be thought to be extraperitoneal or even to be absent, hence we should look for this fossa and feel behind the cecum and colon when the appendix is not readily found.

The *retrocolic fossæ,* external and internal, are occasionally present behind the ascending colon. On raising the cecum they are seen to open downward, when present, and are likely to lodge the distal end of the appendix.

The Colon.—The large intestine (Figs. 109, 114, 123, 128), from the tip of the cecum to the point where the mesorectum ends, opposite the third sacral vertebra, averages 140 cm. ($4\frac{2}{3}$ ft.) in *length* in the male, and 5 cm. (2 in.) less in the female. Its **diameter** decreases from above downward, measuring 3.5 cm. ($1\frac{1}{2}$ in.) at the lower end of the sigmoid flexure and 7.5 cm. (3 in.) in the cecum. It varies with the fulness or emptiness of the gut, which is liable to enormous **dilatation**, if this is gradually produced. In some cases of intestinal obstruction, situated low down, the accumulation of feces and gas may so distend the colon that it occupies most of the abdomen, displaces the heart and lungs upward, and causes shortness of breath and palpitation of the heart, which can be relieved only by emptying the bowel. Dilatation of the colon may occur among rachitic infants, temporarily; or it may be associated with hypertrophy of the bowel wall, constipation, and abdominal distention. On the other hand, the colon is liable to be the seat of **stricture**, cicatricial or malignant. The tendency to the latter increases from above downward, being most common at the narrowest part, *i. e.*, the junction of the sigmoid flexure and the rectum, and least common in the ascending colon. The *flexures* of the colon are also a *favorite situation* for stricture. Tuberculous inflammation, with induration, thickening, and stricture, occurs in the colon as well as in the ileocecal region. The *percussion note* of the colon is of a higher pitch than that of the stomach and lower than that of the small intestine, owing to the difference in size and in the thickness of the walls. Dulness on percussion in the flanks, disappearing when the patient is turned on the side, may be due to an abundance of fluid feces in the colon.

Capacity.—The colon of an infant six months old holds one pint (500 c.c.), that of a child two years old, two to three pints (1000 to 1500 c.c.),

and that of an adult nine pints (4500 c.c.). It is useful to remember these figures in irrigating the colon. No attempt should be made to force fluid above the large intestine. The irrigation of the colon empties the lower ileum by exciting active peristalsis. Large amounts of fluid may be absorbed by the colon when injected under slight pressure, 15 cm. (6 in.) in an *enteroclysis*. The colon is so arranged as to *surround the small intestine* in a circuit from right to left.

The colon is **characterized** by (1) three longitudinal bands or teniæ separating (2) three rows of alternating sacculi (haustra) and constrictions (plicæ); (3) the appendices epiploicæ. Of the **three longitudinal bands** or teniæ, the one along the anterior surface is the longest and most prominent. As they start from the base of the appendix this anterior band is most useful in helping us to find the latter. They measure about 12 mm. ($\frac{1}{2}$ in.) in width and are about half as long as the actual length of the large intestine. Accordingly they pucker up the intervening intestinal walls into three rows of pouches or sacculi, alternating with constrictions, so that if these bands be dissected off, the gut will be made much longer and of uniform contour. They disappear in the lower part of the sigmoid flexure.

Between the three bands the longitudinal fibers are sparingly present, hence the walls of the *sacculi and plicæ* are made up of all layers. The anterior and inner of these bands are useful in operations to distinguish the large from the small intestine. As these bands are conspicuous only when covered by peritoneum, the posterior one along the attached border is of little use as a guide in the retroperitoneal lumbar operations (lumbar colotomy, etc.). In cases of very great distention the teniæ, as well as the sacculi, are temporarily less noticeable or even effaced. In such a case we can recognize the large intestine by the presence of the third characteristic, the **appendices epiploicæ**. These are small pouches or tassels of peritoneum containing more or less fat and attached to the peritoneal covering of the large bowel, except the lower rectum. They are seen especially along the internal band, and are most numerous in the lower part. They therefore afford no help in identifying the colon through the loin, along its attached or non-peritoneal area. The lesser mobility, larger size, and the absence of the palpable ridges due to the valvulæ conniventes also help in identifying the colon.

Solitary *lymphoid follicles* are most numerous in the cecum and appendix, and occur throughout the large intestine. Hernia-like *diverticula*, usually multiple, may occur throughout the colon. They may sometimes lodge fecal concretions, and by ulceration and perforation (diverticulitis) become the cause of peritonitis.

The large intestine is *palpable* throughout except at and near the flexures which are deeply placed. In the lumbar regions also the colon, unless distended, lies well back and is covered by coils of the small intestines. Hence, save at the flexures, tumors of the colon, even when of moderate size, can be well made out, the progress along the colon of an intussusception can often be carefully watched, as well as the effects of the injection of fluid or gas for its reduction. The outline of the colon in

cases of fecal accumulation can also be distinctly defined. In *distention* of the large intestine from any cause the front of the belly is often comparatively flat, as long as the distention is not excessive and is confined to the large bowel, while the two sides and the region just above the umbilicus are prominent. The reverse is the case in distention of the small intestine.

Vessels and Nerves.—The *colic branches* of the *superior mesenteric artery* supply as far as the splenic flexure (the end of the midgut) and, in the left part of the transverse colon, anastomose with the branches of the *inferior mesenteric artery,* which supplies the large intestine below this point. The *veins* enter the portal circulation.

The **lymphatic vessels** of the ascending, transverse, and descending colon enter the mesenteric nodes, those of the sigmoid flexure the inferior mesenteric group of pre-aortic nodes. All the lymphatics entering the above nodes have first traversed small nodes accompanying the arterial branches which pass to the intestine.

The **nerves** are from the *sympathetic plexuses* and accompany the arteries. Those which supply the cecum, ascending colon, and right half of the transverse colon come through the superior mesenteric plexus from the celiac plexus; while those supplying the left half of the transverse colon, the descending and the sigmoid colon, come through the inferior mesenteric plexus from the aortic plexus.

The Ascending and Descending Colons.—The ascending colon and descending colon are *vertically placed* in the lumbar and hypochondriac regions in front of the lateral border of the quadratus lumborum and of the lower part of the right kidney and the lower part of the outer border of the left kidney. Hence abscess of the kidney may perforate the colon retroperitoneally. The *guide to the colon* by the lumbar approach is the *outer border of the quadratus lumborum muscle,* below the kidney. The second portion of the duodenum is to the inner side of the ascending colon. The *descending colon* is *more laterally placed* than the ascending, and hence is more accessible through the loin. The ascending colon averages 12.5 cm. (5 in.) from the ileocecal valve to the under surface of the right lobe of the liver (impressio colica), on the right of the gall-bladder. The descending colon averages 21 cm. (8½ in.) to the iliac crest, the commencement of the sigmoid loop.

A **mesentery**, varying from 2.5 to 7.5 cm. (1 to 3 in.) in length, is provided for the ascending colon in only 26 per cent. of cases, and for the descending colon in 36 per cent. (Treves); in the other, 74 or 64 per cent. respectively, the peritoneum covers the front and sides only, leaving a wide strip uncovered posteriorly. This strip varies in width, averages one-third of the circumference of the colon, and is wider the more distended the colon becomes. It is here that the colon was *opened in lumbar colotomy,* hence the presence of a mesentery was of importance in connection with this operation, especially in the case of the descending colon, which was the portion most often opened. Along this strip the back of the colon is in relation with the loose subperitoneal tissue in which a retrocolic abscess may form, secondary to inflammation of a high retrocolic appendix or of the colon itself.

The ascending colon may be absent when the cecum has not descended, but the descending colon shows but little tendency to variation and is the only part of the gut, below the duodenum, that retains its original vertical, fetal position.

The Transverse Colon.—The transverse colon averages 50 cm. (20 in.) in *length,* but is very variable. As it is longer than a straight line between its two ends, it describes a curve *convex forward* and *downward.* As a rule, it *lies* above the level of the umbilicus, but in 29 per cent. of cases it is below this line, and in some cases it is *displaced downward* in an abrupt V- or U-shaped bend, which may even reach the symphysis, while the two flexures are normal in position. Such bends are due to habitual constipation or to congenital causes (Treves). In the majority of cases the central portion of the transverse colon is in the line separating the epigastrium from the umbilical region.

Relations.—*Above* is the under surface of the liver, the gall-bladder, the great curvature of the stomach, and the lower end of the spleen; *behind* is the second part of the duodenum, the pancreas, and the transverse mesocolon; *below* is the small intestine, and *in front* the great omentum and anterior abdominal wall.

The transverse colon always has a *mesentery* (*mesocolon*) (Fig. 115), which from its length renders this the *most movable portion* of the colon, hence it is often found in the sac of an umbilical hernia. Its anterior surface along the anterior band is *adherent to the great omentum,* which separates it from the anterior abdominal walls. Through the omentum the sacculi of the colon can usually be seen. By raising up the omentum we expose the transverse colon adherent to it. This portion of the colon and the omentum shut in the coils of the small intestine above and in front respectively. The part of the omentum between the great curvature of the stomach and the transverse colon (*gastrocolic ligament*) connects the two, so that the latter moves with the stomach. It overlies the latter when it is empty, and is pushed down by it when it is full. Many errors in diagnosis are attributable to fecal masses impacted in the transverse colon.

Owing to the close relation of the **hepatic flexure** and the right end of the transverse colon with the gall-bladder, ulceration of the latter, due to gallstones, has sometimes involved the adherent colon, and the gallstone has thus entered the colon and been passed per anum. It is often found stained with bile postmortem. If the gall-bladder cannot be approximated to the duodenum or jejunum in cholecystenterostomy, the anastomosis can be readily made with the colon, and the short-circuiting of the bile has had no untoward effect on the patient's condition. Hepatic abscess has also ruptured into and been discharged through this part of the colon. I have also seen a fistulous opening between the transverse colon and the stomach in case of a carcinoma of the latter.

The **splenic flexure**, at the left end of the transverse colon, is in contact with the lower end of the spleen in the left hypochondrium. It lies behind the stomach and is higher and more dorsal than the hepatic flexure.

Both flexures of the colon, deeply placed at the back of the hypochondriac regions, are *held by bands of peritoneum* passing from the hepatic flexure to the under surface of the liver (*lig. hepatocolicum,* Joessel), an inconstant expansion of the hepatoduodenal ligament, and from the splenic flexure to the diaphragm opposite the tenth and eleventh ribs (*lig. phrenocolicum*). The latter, derived from the left end of the great omentum, is also called the *sustentaculum lienis,* as it helps to support the spleen.

The Sigmoid Colon or Flexure.—The sigmoid colon or flexure *extends* from the level of the left iliac crest to the third sacral vertebra at the end of the mesenteric attachment, including the part formerly called the first piece of the rectum. Including the latter it forms an *Ω-shaped loop* averaging 44 cm. (17½ in.) long. The sigmoid flexure is *normally found* in great part in the pelvis and not in the iliac fossa, unless displaced out of the pelvis by its own distention or that of the bladder, rectum, or female pelvic organs, with which, as well as with the small intestine and often with the appendix or even the cecum, it is in relation in the pelvis, and to which it may become adherent in pelvic inflammation. If the mesentery of the sigmoid colon is unusually short, the latter may be very largely in the left iliac fossa. The division of the sigmoid colon into the iliac and pelvic colon (Jonnesco), according as it lies above or below the pelvic brim, serves no useful purpose, and the portions of the loop in the iliac fossa and pelvis vary constantly with the condition of the pelvic viscera, etc. This loop is liable to enormous *dilatation* from fecal accumulation, and has been known to reach up to the liver.

In the newborn the sigmoid loop, usually filled with meconium, may reach over to the right side, owing to its long mesentery. Under such conditions the opening of this loop in the left groin to establish an artificial anus, which is required in cases of congenital deficiency of the rectum, might be difficult. Yet, according to Curling, it is found on the left side in 85 per cent. of cases in young infants.

The sigmoid loop is provided with a **constant mesentery,** 3 to 8.5 cm. (1¼ to 3½ in.) long, from parietal to intestinal attachments, which connects it with the left iliac fossa. The *line of attachment* of this mesentery crosses the psoas muscle to reach the pelvic brim at about the bifurcation of the left common iliac vessels and the sacro-iliac articulation, or a little above it. Then it turns sharply downward and extends to the middle of the third sacral vertebra. The two attached extremities of this loop are only 7.5 or 10 cm. (3 or 4 in.) apart, and may be nearer abnormally. Hence, since the loop itself is fairly movable, the conditions are such that we can easily see how a twist or **volvulus** may occur, as it does, more often in this portion of the bowel than in any other.

On the left or lower aspect of the root of the sigmoid mesocolon is oftentimes a peritoneal pouch, the **intersigmoid fossa,** in which the occurrence of at least two cases of strangulated *sigmoid hernia* has been reported. This fossa is *funnel-shaped,* and its *opening* looks downward and to the left, and is generally over the bifurcation of the iliac vessels. It is *found* by turning the flexure to the right. The fossa is 2.5 to 6 cm.

(1 to $2\frac{1}{2}$ in.) deep, is more constant in the infant than in the adult, and is caused by a fold due to the sigmoid artery.

The **rectal or colon tube** cannot be passed beyond the sigmoid loop under normal conditions, but the irrigation of the colon can be accomplished with the tube in this loop. In case of habitual constipation a doughy tumor may be present in the sigmoid colon. Such tumors, and those of other kinds in this part of the bowel, may press upon the branches of the left lumbar plexus, such as the anterior crural or obturator, and cause neuralgia. The sigmoid, descending and ascending colon, as well as the cecum may be found in inguinal or femoral herniæ. The large intestine may be altered in position by a misplaced or enlarged kidney.

Colotomy.—Colotomy may be performed in either lumbar region, especially in the left, to establish an artificial anus when there is obstruction below.

Lumbar colotomy (Amussat's operation) is now rarely employed. It is preferably done on the left side, for it is nearer the anus. A vertical line 12 mm. ($\frac{1}{2}$ in.) behind the centre of the iliac crest represents the course of the colon. This line crosses the guide to the colon, the outer border of the quadratus lumborum. (See Lumbar Region.) The line of the ascending colon is a little more mesial than that of the descending colon. The kidney intervenes between the colon and the parietes in the upper part of the iliocostal space. In the lumbar operation the colon is opened retroperitoneally along the attached area, which, in the empty state, varies from 20 to 25 mm. ($\frac{4}{5}$ to 1 in.) in width, and in the distended condition may reach 5 cm. (2 in.) or more (Braune). In 36 per cent. of cases the descending colon has a mesentery, and so cannot be readily reached extraperitoneally. On the retroperitoneal surface neither the appendices epiploicæ nor the longitudinal bands aid us in distinguishing the colon, for the latter are not visible and the former are not present.

In the newborn the *ilio-costal space* is very limited and entirely occupied by the kidney, so that, although the colon is then altogether outside of the kidney, colotomy is done in the inguinal region.

Inguinal colotomy (Littre's operation) is the one most often practised in adults as well as in children. The *oblique incision* is parallel with and a short distance (3.5 cm.; $1\frac{1}{2}$ in.) from the outer half of Poupart's ligament, and may be intermuscular. The opening is made in the sigmoid loop preferably at its lower end, for the loop then serves as a fecal reservoir, the movements are more formed, and there is much less danger of incontinence. If the artificial anus is to be only temporary, a transverse spur of mucous membrane is made opposite the lower end of the opening to prevent the contents passing into the lower segment of the gut. If the opening is to be permanent, the distal end is closed and dropped back and the proximal end is brought out through the wound and then passed beneath the skin (or skin and fascia) to an opening below the outer end of Poupart's ligament and sutured there. The pad of a truss, applied over the 2.5 to 5 cm. (1 to 2 in.) of skin beneath which the gut passes, will control all passages through the opening. We easily distinguish the

sigmoid loop from the coils of the small intestine, which often present themselves, by the bands, sacculi, and appendages, and by its position.

The Liver.—The liver (Figs. 109, 121, 122, and 126) is the largest gland in the body, and on account of its bulk, as well as its position, it is much *exposed to injury.* In **size** it averages 17.5 to 25 cm. (7 to 10 in.) from right to left, 7.5 to 15 cm. (3 to 6 in.) from before backward, and 15 to 17.5 cm. (6 to 7 in.) from above downward, in the right lobe. It is larger in men than in women, and, pathologically, it is subject to great variations in size and weight, especially to enlargement. *At birth* it is relatively much larger than in the adult, reaching below the costal margin and as far to the left as the spleen. Owing to its size and weight in the infant, a baby is not laid on its left side soon after feeding, on account of the pressure of the right lobe on the stomach. It is not until the sixth or eighth year of childhood that the anterior border becomes level with the right costal margin.

Its **weight** is between 50 and 60 ounces, but varies according to its size and the amount of blood contained. As it contains nearly half a kilogram of blood, it weighs much more during life than at postmortem. At birth it is one-twentieth of the weight of the body; in the adult male one-fortieth. Its volume is about 95 cubic inches.

The **consistency** of the liver is *firmer* than that of other glands, but it is *friable.* This fact, together with its size, fixity, and close parietal relations, explains why it is more often *ruptured* from contusions and falls than any other abdominal viscus. Ruptures occur most commonly near the supporting ligaments. Free *hemorrhage,* often fatal, results from such an injury because the hepatic veins are held open by the liver substance, to which their walls are adherent, there are no valves in the portal and hepatic veins, and the latter connect directly with the inferior cava.

The liver is *moulded* to the surrounding organs which give it its **shape,** that of an ovoid bevelled off on its under part, especially at the left end. When examined in position we find **three surfaces**: a *posterior,* resting against the upper part of the posterior abdominal wall, here formed by the diaphragm; *an upper,* fitted into the vault of the diaphragm, and hence looking forward also in front; and *an inferior,* which rests upon the abdominal viscera as upon a pillow. The *left lobe,* large at birth, diminishes so much in size in early life that the falciform ligament, which represents the division between the right and left lobes and contains the round ligament in its free edge, is displaced to the right of the median line. Hence median abdominal incisions pass the umbilicus on the left to avoid incising these ligaments in regaining the median line above the umbilicus.

Position.—The liver *lies* in the right hypochondrium and the epigastrium, and extends into the left hypochondrium a distance varying from 3.5 or 5 cm. (1½ or 2 in.) beyond the left margin of the sternum to the left mammary line. When enlarged it extends farther to the left, under the left false ribs and in front of the stomach and the spleen, as in the child. The bulk of the liver and the entire right lobe is to the right of the median line.

Throughout its extent it occupies the vault of the diaphragm, hence **its upper limit** is on a level with the lower end of the mesosternum in the middle line, the middle of the fourth intercostal space in the right mammary line, the seventh rib at the right side, and the upper end of the fifth space in the left mammary line. **Behind** it becomes *superficial* below the right lung, opposite the tenth and eleventh thoracic vertebræ and ribs, but its upper limit, covered by lung, is level with the ninth thoracic vertebra. It is overlapped **above** by the thin margin of the lung, below this by the costophrenic sinus. Over the latter area pleuræ and diaphragm intervene between the liver and the chest wall. Hence a *penetrating wound* in the area between the upper extent of the liver and the lower limit of the lung[1] (see Lungs, p. 245), or the line of absolute liver dulness, may involve the pleura, right lung, diaphragm, peritoneum, and liver, penetrating four layers of pleura. Or, if the wound be a little lower, it may escape the lung and only involve the two layers of pleura of the costophrenic sinus, in addition to the diaphragm, liver, etc. The alteration in position of the liver, according to the position of the body or the movements of respiration, should be remembered in diagnosticating the course and effects of a wound from the situation of the external wound. **In front** the xiphoid cartilage and the costal cartilages, from the sixth to the ninth inclusive, and *on the right side* the ribs, from the seventh to the eleventh inclusive, cover the convex surface of the liver, the diaphragm being interposed.

In *percussing* the chest from above downward we find a region of *relative liver dulness* where the liver is overlapped by lung. This dulness increases as we pass to the lower border of the lung, where we reach the line of *absolute liver dulness*. This is at the sternoxiphoid articulation in the median line, the sixth intercostal space in the right mammary line, the seventh rib in the axillary line, and the lower border of the ninth rib in the scapular line. The line of relative and absolute liver dulness is liable to variation with the changes in position of the diaphragm in respiration; in diseases affecting the extent and condition of the lung; in pleuritic effusions; in abdominal tumors, ascites, or distention; and in variations in position or size of the liver.

The **lower limit** of the normal adult liver corresponds to that of its *anterior border* in front. In the *median line* it is at a point midway between the sternoxiphoid articulation and the umbilicus; in the *mammary line* at, or 12 mm. ($\frac{1}{2}$ in.) below, the costal margin; on the *right side* it follows the tenth and eleventh ribs, without extending beyond the anterior end of the latter, as a rule; and *behind* it reaches the level of the lower end of the eleventh thoracic vertebra. This would represent the *lower limit* of the *liver dulness* except behind, where it is continuous with the dulness of the lumbar region. If on the right side one can palpate the liver below the tenth and eleventh ribs in quiet breathing, the liver is enlarged or displaced downward. On the extreme right the

[1] In the fifth or sixth intercostal space in front, the sixth at the side, and the seventh, eighth, or ninth behind.

lower limit of the liver may reach the level of the second lumbar spine. In the *subcostal angle* the liver is in contact with the anterior abdominal walls, and its *lower limit* is represented by a line drawn from the ninth right to the eighth left costal cartilage. Here one can *palpate* the lower or anterior margin of the liver when the abdominal walls are thin.

The liver is quite *movable,* and its lower limit is therefore subject to variation from physiological and pathological causes. Thus, owing to its intimate relations with the diaphragm, it moves upward and backward in expiration, downward and forward in inspiration, so that with a deep inspiration its anterior border may descend below the costal margin in the right hypochondrium, even in the reclining position. In the *supine position* the edge of the liver is 12 mm. ($\frac{1}{2}$ in.) above the costal margin on the right side in front; in the *erect position* it descends to 6 or 12 mm. ($\frac{1}{4}$ or $\frac{1}{2}$ in.) below this margin.

We have already noted the difference in position in children up to the sixth or eighth year. **In women** the liver is apt to reach a lower level, owing to the use of corsets, and in those who lace tightly it may be pushed down even to the iliac fossa. In such cases of "*corset liver*" the right lobe is marked by a deep constricting *furrow,* due to the pressure of the costal margin. In this furrow the transverse colon or loops of the small intestine may sometimes be found, and prevent the recognition of the continuity of the lower portion with the liver, by percussion or palpation. Hence it has been mistaken for a movable kidney. Among those who have never worn tight corsets, as well as among those who have, a long tongue-shaped process may project downward from the right lobe near the gall-bladder. This is known as "Riedel's lobe," and is often associated with cholelithiasis.

In *uniform enlargements* of the liver, from any cause, it is displaced downward, where we can diagnosticate the enlargement by percussion and palpation. Enlargements of the liver also cause a bulging of the right lower ribs and costal cartilages. When, however, the upper part of the right lobe is involved in abscess or hydatids, the enlargement and the area of dulness extend upward, raising the diaphragm and encroaching upon the right lung. In emphysema, pleurisy with effusion, and other conditions associated with distention of the right side of the thorax, the lower level of the liver is lowered. On the other hand, in phthisis, collapse or retraction of the lung, and diaphragmatic hernia, also when the liver is abnormally small and in conditions involving distention of the abdomen, the lower level of the liver is raised, so that we may have tympanitic resonance over the costal margin. In cases of suspected gastric or intestinal perforation and in abdominal injuries absence of liver dulness in front, when the patient is supine, is an important sign, indicating the presence of gas between the liver and the body wall in front of it.

From the above we obtain the limits between which the liver is *accessible to operation.* In the upper part of this area the liver lies deeply covered by the lower margin of the lungs, etc. Above the lower limit of the pleura we must pass through the latter and the diaphragm to reach

the liver. This is necessary when the trouble affects the upper part of the liver, and may be safely done by suturing the diaphragm into the thoracic opening and then penetrating the diaphragm. If we resect the tenth rib *in the right axillary line* we find the diaphragm with no intervening pleura, but on penetrating the diaphragm we open the peritoneal cavity and disclose the lower and outer portion of the right lobe of the liver.

The liver is **held in position** by the attachment of the hepatic veins to the vena cava and of the fibrous tissue near the vein to the diaphragm, by its attachment to the diaphragm, within the area embraced by the coronary ligament, by the latter ligament, by intra-abdominal pressure exerted through the viscera on which it lies, and by the lateral and suspensory ligaments. The latter ligament is of little or no service in suspension. Although the liver is firm in position as compared with other intraperitoneal organs, yet, as we have seen, it is also subject to variation in position. From the relaxation and stretching of its ligaments and of the abdominal walls, especially in women after childbirth, a "*dislocation*" of the liver or a "*wandering liver*" may result. A more moderate downward displacement, hepatoptosis, is not uncommon, and several have been operated on successfully by hepatopexy. Most cases have general abdominal ptosis and rarely demand operative treatment. With its descent a forward rotation or tilting occurs, so that its diaphragmatic surface comes in contact with the abdominal wall.

According to Hasse the liver is *stretched in inspiration* and *compressed in expiration.* Doubtless the movements of respiration stimulate its circulation, and probably on this account it is placed between the diaphragm and the abdominal walls. Thus, a bon vivant or one of active habits suddenly confined to bed, by a broken limb, etc., becomes bilious from a congestion of the portal circulation, owing to the little stimulation it receives from the movements of respiration, which is now quiet.

Relations.—The diaphragm above separates the **upper surface** of the liver from the *pleural and pericardial cavities.* The latter corresponds to a flattened area on the upper surface of the left lobe. The close relations of the liver with the pleura, lungs, and heart explains how hydatid cyst or abscess of the liver may burst into the pleura or lung, or even into the pericardium. Thus it happens that pieces of liver, disintegrated, it is true, may literally be coughed up. Similarly empyema has been known to penetrate the diaphragm and give rise to a subdiaphragmatic or an hepatic abscess. The liver may also be damaged when the *right lower ribs* are fractured, owing to their close relations. The broken ends of the ribs have, in some cases, been driven into the liver through the diaphragm. If the smooth upper surface of the liver is roughened by inflammation its movements in respiration give rise to a friction sound similar to that in pleurisy.

The **posterior surface** of the liver *rests upon* the right suprarenal body, to the left of this it is grooved for the vena cava, and farther to the left it lies upon the crura of the diaphragm, with the various vessels and nerves between or within them, and the esophagus. In case of great enlargement

of the liver these structures may suffer a certain degree of compression. The possibility must be admitted of a *rupture of the liver* without tearing the peritoneal coat. Such injuries are not likely to be fatal. They may reach the surface of the organ behind, on the fairly extensive non-peritoneal surface. Here also a *wound* may occur or an *incision* be made into the liver without opening the peritoneal cavity, but, owing to its position, only after passing through the pleural cavity.

The **under surface** of the *right lobe* is *in contact with* the upper half or two-thirds of the right kidney and the suprarenal capsule, to the left of this with the duodenum (first and second parts), and in front of these with the colon. To the left of the neck of the gall-bladder lies the pyloric end of the stomach in relation with the quadrate lobe. The *lower surface* of the *left lobe* projects as the tuber omentale, which rests upon the lesser omentum, and in front of and to the left of this it is concave, where it covers the lesser curvature, cardia, and part of the anterior surface of the stomach, to an extent varying inversely with the fulness of that organ. It may even cover the fundus of an empty contracted stomach.

From these relations we see that an **abscess of the liver,** after inflammatory adhesion, *may open* inferiorly into the colon, duodenum, stomach, or right kidney, and also that an abscess of or about the right kidney may extend to the liver. More than half of the liver abscesses that rupture do so in an upward direction. Abscess of the liver is usually the result of infection of the portal vein through some of its radicles. When this infection is from a septic process, most often an appendicitis, there are usually multiple embolic abscesses, which follow a suppurative pylephlebitis. Occasionally with pyogenic infection there is a single localized abscess, or a group of several which fuse into one. The common form of localized abscess is due to infection by amebæ coli from amebic dysentery. This form is known as "tropical abscess," owing to its common occurrence, and that of its cause, in the tropics. Abscess of the liver may also follow surgical operations upon the same parts. The secondary or *metastatic abscesses of pyemia* are frequently found in the liver, and, according to Bryant, more often after injuries to the head than after other injuries. Tillaux states that metastatic abscesses are superficial, other abscesses deeper.

We have already seen some of the positions in which hepatic abscesses may perforate; in addition, there may be mentioned the peritoneal cavity and the surface of the body, after adhesion of the liver to the body walls. If the abscess is pointing in the latter position, it is preferably opened below the costal margin when it is accessible there.

Hydatid cysts occur more often in the liver than in all other viscera taken together, for the embryos of the eggs of Tenia echinococcus readily penetrate the vessels of the walls of the stomach and intestines, and are likely to enter a tributary of the portal system and be carried to the liver. These cysts may discharge themselves in the same directions as hepatic abscesses.

Coverings and Structure.—The liver is covered by *peritoneum* except (1) over the areas between the layers of peritoneum which constitute

the ligaments by which it is held in position; (2) along the transverse fissure, where the lesser omentum is attached and the vessels and ducts enter or emerge; and (3) at the bottom of the fissure for the gall-bladder, where the latter intervenes between the liver and peritoneum. Hence most operations, wounds or affections of the liver, which reach the surface, must involve the peritoneum.

Beneath the peritoneal coat, or in place of it where it is wanting, is a thin coat of *fibrous tissue,* which at the transverse fissure accompanies and loosely invests the vessels and ducts throughout the liver. This fibrous tissue, *Glisson's capsule,* forms a lattice-work throughout the liver, which is thereby divided up into minute lobules, 1 to 2 mm. in diameter. This fibrous lattice-work may become *swollen in cirrhosis* or in hepatitis. In the latter the swelling is the result of acute inflammation, and the liver is enlarged and tender. In cirrhosis the swelling is usually due to chronic alcoholic irritation, which, if continued, results in hypertrophy of the fibrous tissue. This produces a large, hard liver, the first stage of cirrhosis. The swelling or hypertrophy, obstructing the flow of bile from the lobules, causes a certain degree of jaundice, from the absorption of the coloring matter, and dyspepsia is a constant symptom from portal congestion. The subsequent contraction of the new fibrous tissue renders the liver hard, fibrous, and often smaller than normal, and compresses the branches of the portal vein. This causes great congestion of the parts which feed the portal vein, *i. e.,* the stomach, intestines, pancreas, and spleen, with enlargement of the latter two. This results in varicose veins of these parts, from which serous exudations (*ascites*) and *hemorrhages* may occur, and aggravates the functional disturbance of the digestive tract. According to some the concurrent toxemia is also an important factor in producing ascites. The surface of the liver becomes rough and irregular (*hobnail liver*), owing to the contraction of the fibrous lattice-work which reaches the surface.

The liver may be *greatly and uniformly enlarged,* even so as to reach the umbilicus, in certain diseases of the heart and lungs where the flow of blood from the hepatic veins into the vena cava is impeded, owing to the congestion of the right heart. Fatty degeneration is another condition which may cause an enlargement of the liver, sometimes of enormous size.

Vessels and Nerves.—These, invested by Glisson's capsule, enter the liver at the transverse fissure, which they reach by ascending between the two layers of the small omentum near its right margin and in front of the foramen of Winslow.

The **hepatic artery** supplies largely the duct and vessel walls and the fibrous tissue of the liver. Brewer has called attention to the frequency of anomalies in the position and branching of this vessel, which, however, are seldom of surgical importance. The **portal vein** brings by far the greater part of the blood to the liver and practically all that which reaches the liver cells. It comes from all the organs concerned in digestion and absorption. As the right primary branch of the vein is larger and a direct continuation of the main vein, embolic material carried to the

liver commonly involves the right lobe. The results of *obstruction of the portal vein* are seen in enlargement, congestion, varicosities, hemorrhage, serous exudation within (diarrhea) and without (ascites), and impairment of the function of the viscera containing the sources of the vein (Fig. 120).

In such cases the *anastomotic circulation of the portal system* comes into play, viz., certain of the superficial branches on the liver with the phrenic veins; the veins of the round ligament with the epigastric veins; the hemorrhoidal veins with branches of the internal iliac; the gastric with the esophageal veins; and small branches on the pancreas and on the parts of the intestine destitute of a mesentery with the veins of the parietes and viscera (kidneys), with which they are in contact. Operations are now done to increase this compensatory circulation by producing adhesions between the omentum and parietal peritoneum by

Fig. 120

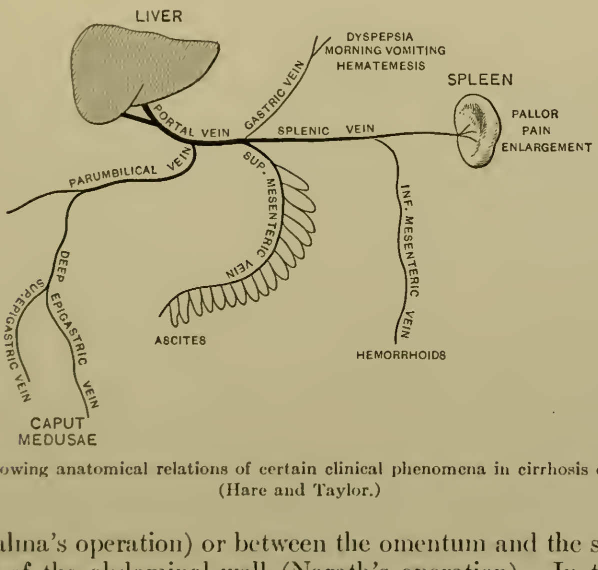


Diagram showing anatomical relations of certain clinical phenomena in cirrhosis of the liver. (Hare and Taylor.)

suture (Talma's operation) or between the omentum and the subcutaneous tissue of the abdominal wall (Narath's operation). In the former operation attempts are also made to effect adhesions between the liver and spleen and the diaphragmatic peritoneum.

Lymphatics.—The lymphatics of the liver, both superficial and deep, terminate in several groups of nodes: (1) The nodes of the hilum, usually in two hepatic chains along the hepatic artery and the bile ducts; these form the most important group and next to them. (2) Mediastinal nodes (*a*) around the inferior cava and (*b*) behind the xiphoid. (3) Peri-esophageal nodes continuous with the coronary nodes of the stomach. (4) The nodes around the celiac axis. One or more of these groups of nodes may be involved in hepatic cancer.

The **nerves** are from the *left vagus* and the *celiac plexus* (sympathetic). The former filaments, fewer in number, pass from the lesser curvature

of the stomach between the folds of the small omentum. The *pain over the right shoulder* in liver disease, such as hepatitis, etc., is a *reflex* in the *supra-acromial nerve* due to the fact that it is a branch of the fourth cervical nerve, which also helps to form the phrenic nerve, filaments of which enter the liver from the diaphragm. This reflex pain is commonly on the right side, for the right lobe is usually chiefly involved. The most sensitive part of the liver is that about the neck of the gall-bladder and the common bile duct, which receive filaments from the last two thoracic and first lumbar nerves, which also pass onto the diaphragm. This explains the diaphragmatic spasm of gallstone colic and the occasional disturbance of diaphragmatic respiration in operations in this region (Mayo).

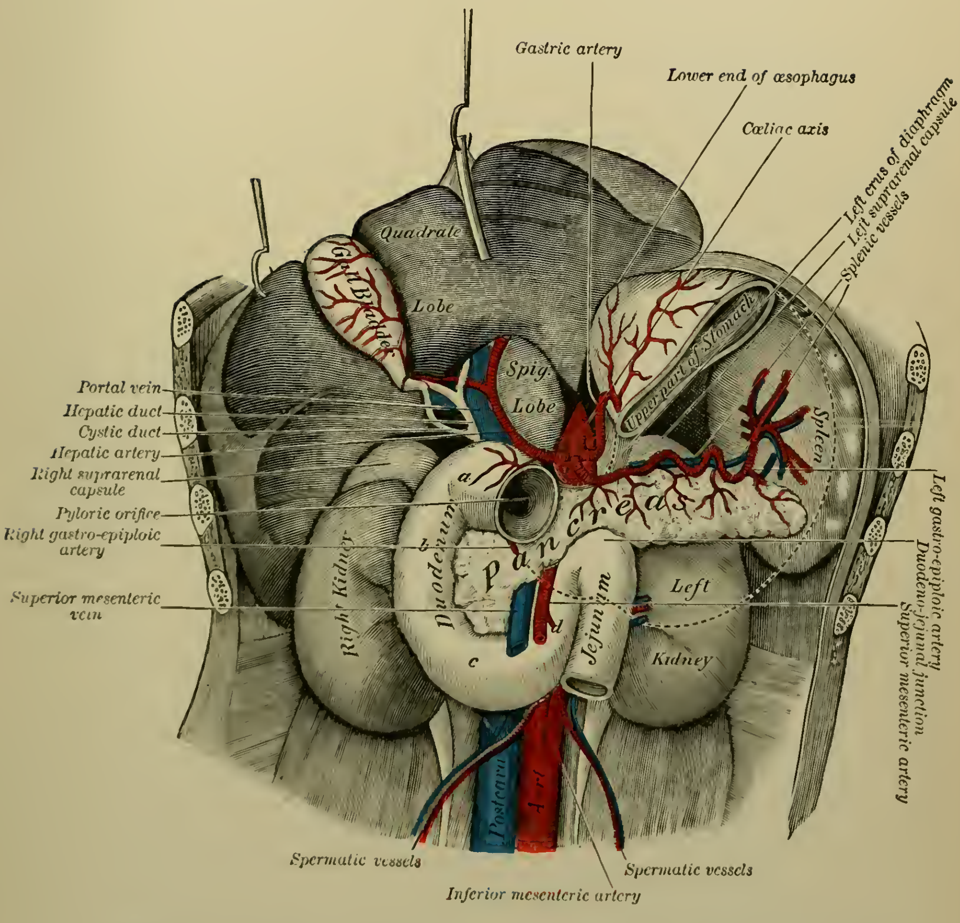
Carcinoma of the liver is a common condition, not as a primary but as a secondary or metastatic growth, usually from the stomach, intestines, uterus, or mammæ. These growths are, as a rule, multiple and diffuse. When not diffuse a tumor of some size may be *removed,* for a considerable part of the liver may be removed without disturbance of function. Experimentally three-fourths have been safely removed in animals. The part remaining hypertrophies, and probably the liver may be regenerated. In such cases the escape of bile is not usual, nor is it necessarily fatal. *Hemorrhage* can be controlled by the cautery, where the vessels are not large, or by the clamp, by crushing or by suture of the wound or of vessels, where there are larger vessels which, as we have seen, are held open by their connection with the tissues in which they lie. As the blood pressure within the liver is very low, slight pressure also checks hemorrhage.

Anomalies are *not common* in the liver. The *left lobe* may be unusually small or large, or a portion of it may be connected with the rest by a pedicle of peritoneum containing only bloodvessels, and so a movable kidney or an abdominal tumor may be simulated. The liver is found on the left side in transposition of the viscera.

The Gall-bladder.—The *pear-shaped* gall-bladder (Figs. 109, 110, 121 and 122) is 6.5 to 10 cm. ($2\frac{1}{2}$ to 4 in.) *long* by 4 cm. ($1\frac{1}{2}$ in.) *wide* at the fundus, and will *contain* about 30 gm. (1 oz.). Its walls are very elastic, and hence may become greatly *distended* from the obstruction of the cystic duct and some forms of obstruction of the common duct, so as to contain a pint and more and extend even below the umbilicus. It is so *lodged* in the cystic fossa between the right and quadrate lobes of the liver that its larger end, or *fundus,* projects forward, downward, and to the right, beyond the notched anterior margin of the liver, so as to *lie* behind the abdominal wall just below the edge of the ninth right costal cartilage and just lateral to the right rectus muscle. When distended it is usually protruded downward in a line passing somewhat to the right of the umbilicus. The fundus lies below the level of the neck in the upright posture, but drains back to it in the supine position. When *enlarged* it can be percussed but better palpated external to the rectus muscle. Such a tumor moves with respiration, for it is connected with the liver. It is often contracted and smaller

PLATE XXXIV

FIG. 121



Viscera of the Upper Part of the Abdomen. The liver is lifted up, showing the gall-bladder and the upper part of the gall ducts. (Testut.)

than normal, especially in cases of long-standing inflammation, when it may become almost obliterated.

When normal the gall-bladder cannot be palpated through the abdominal wall. It may lie entirely under cover of the liver, whose anterior border is usually notched (the cystic notch) over the fundus of the gall-bladder. Its narrow end or *neck extends* backward, upward, and to the left toward the transverse fissure, where, curving first to the right and then to the left in an S-shaped manner, the *cystic duct* leads off from its upper part and continues its spiral course.

Fig. 122

Relations of the gall-bladder and bile duct. (Mayo.)

It is *held in position* by the attachment to the liver of its upper one-eighth to one-third by areolar tissue and of its under surface and sides by peritoneum reflected from the liver. Occasionally the peritoneum completely surrounds the gall-bladder, forming a short *mesentery* which suspends it from the under surface of the liver. More commonly only the posterior half or so of the organ is provided with a mesentery. At

times an extension outward of the free border of the small omentum to the lower surface, even as far as the fundus, forms a posterior mesentery (Brewer). Also a peritoneal fold occasionally connects the body of the gall-bladder with the anterior aspect of the transverse colon. Normally the gall-bladder can be readily stripped by blunt dissection from the under surface of the liver after its peritoneal attachments are divided.

The *upper surface* is in relation with the liver, the *under surface* is in contact with the transverse colon in front, and with the bend between the first and second portions of the duodenum, and oftentimes with the pyloric end of the stomach, behind, near the neck. These parts are found stained with bile after death, and into these parts gallstones may pass from the gall-bladder after adhesion and ulceration. A fistulous tract from the gall-bladder most often opens on the surface of the abdominal wall and allows the escape of gallstones and fluid contents.

Beneath the partial peritoneal covering the wall is made up of *fibrous tissue* with some *muscular fibers,* principally longitudinal, and it is lined with mucous membrane. The *viscid secretion* of the latter mingles with the bile, hence the bladder is more than a reservoir. Its secretion is often the principal content of the distended bladder (hydrops of the gall-bladder), as when the cystic duct is obstructed. If its contents are purulent, we call the condition *empyema* of the gall-bladder. In several reported cases the gall-bladder has served as a reservoir for typhoid bacilli, from which the infection has been scattered with the stools. The function of the gall-bladder is probably unimportant. Its capacity of one ounce is trifling in comparison with the twenty-four-hour output of 20 to 30 ounces or more of bile. It has also not been proved that the gall-bladder contracts forcibly when full. It may produce a steady instead of an intermittent flow into the duodenum (Murphy). Absence of the gall-bladder, congenitally or by reason of inflammation or removal, causes no disturbance of function.

The bile is not sterile, but contains a few attenuated bacteria that have survived their passage through the liver. This and interference with drainage of the gall-bladder probably underlies gallstone disease (Lartigau).

Gallstones are frequently present in the gall-bladder, often without giving any sign of their presence during life and only discovered at autopsy. They are *formed* mainly of cholesterine, and vary from a flaxseed to a hen's egg in *size.* The smaller ones may pass through the ducts into the intestine; the larger ones, if passed, enter the bowel through a fistulous opening. It is impossible to feel gallstones through the abdominal wall; in fact, even through the open abdomen one cannot surely say whether a distended gall-bladder has stones in it or not. Though often innocuous, they may provoke *inflammation* of the gall-bladder (cholecystitis) and various obstructive conditions of the bile passages. Cholecystitis is due to an infection by colon, typhoid, or pyogenic bacteria which reach the gall-bladder through the bile ducts, blood, or lymphatics. It may be the seat of a primary malignant growth.

The *opening* of the gall-bladder, done on account of empyema, distention, inflammation, gallstones, etc., is called **cholecystotomy. Cholecystectomy** is the removal of the gall-bladder, which is done on account of a tumor, gangrene, or inflammation with obliterated cystic duct and thickened, contracted bladder walls, etc. When an obstruction of the common bile duct cannot be removed we may open the distended gall-bladder and connect it with the jejunum, duodenum or transverse colon (**cholecystenterostomy**), so that the bile has a new route to the bowel. Nature sometimes performs the same operation by ulceration after adhesion.

Rupture of the gall-bladder as well as of the bile ducts may occur with or without rupture of the liver. It usually takes place close to the neck, and is more likely to occur when the liver is enlarged and the gall-bladder distended. It is not necessarily fatal if the bile is normal, for then it is poor in bacteria and only excites a plastic, adhesive peritonitis which walls off the fluid. It only excites septic peritonitis when suppurative processes have preëxisted in the gall-bladder.

The **lymphatics** of the gall-bladder pass to a chain of nodes which is a satellite of the cystic and common ducts. One is generally found at the junction of these two ducts. In inflammatory conditions they may become so enlarged as to cause obstruction by pressure, and they may be mistaken for a stone in the common duct.

The *cystic artery* which supplies the gall-bladder usually branches off from the hepatic some distance posterior to the cystic duct and reaches the gall-bladder just above its neck. In the occasional cases where it is a branch of the superior pancreaticoduodenal artery it runs along the common duct and is liable to be injured in operations upon that duct. A transverse vein in front of the supraduodenal portion of this duct may also be injured in operations upon it.

The cystic duct (Figs. 110, 121, and 123), 25 to 38 mm. (1 to 1½ in.) *long* (2.5 to 7.5 cm., Joessel) by 3 mm. in diameter, *runs* in the lesser omentum from right to left and somewhat backward and downward to connect the neck of the gall-bladder with the hepatic duct, which it joins at an acute angle to form the common bile duct.

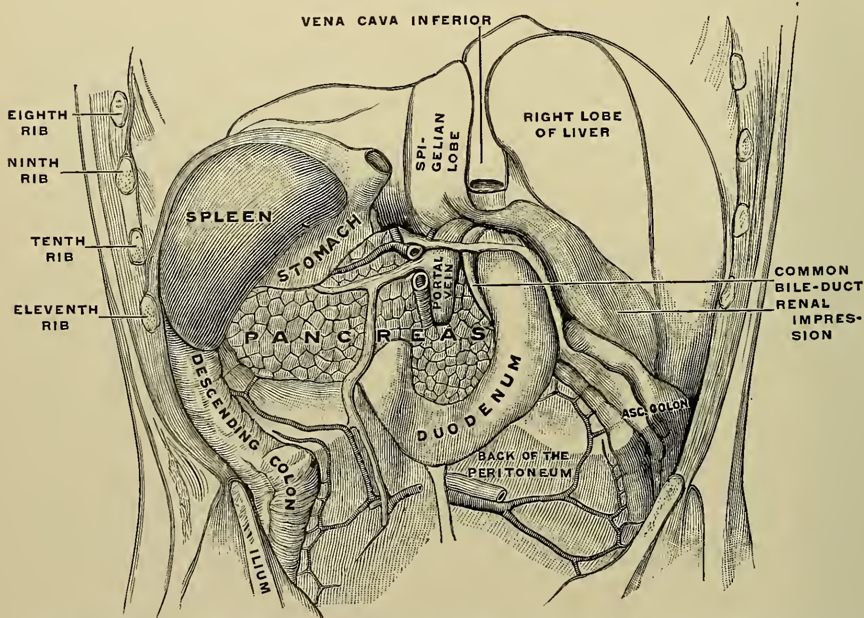
The *spiral curve* of the neck of the gall-bladder and of the adjoining part of the cystic duct corresponds to the *irregular folds* of its lining mucous membrane, which sometimes simulates a spiral valve. The effect of this arrangement is to make it almost impossible to pass a probe along this duct, unless it has previously been distended by the passage of a stone. As it is the *smallest part of the biliary channel*, small stones that pass it easily can usually quickly pass the common bile duct. It is remarkable what large stones pass the cystic and common ducts. The cystic duct may be greatly *enlarged* by the passage of a stone or by distention in chronic cases of obstruction in the common duct. Bile only flows into the gall-bladder when its flow into the duodenum is stopped.

Obstruction of the cystic duct is not followed by jaundice, for the flow of bile into the intestine is not checked, and though the gall-bladder may be distended it is due to its own secretion.

The right and left bile ducts usually *join* one another at an obtuse angle near the *right end* of the transverse fissure, shortly after their exit from the liver, to form the **hepatic duct**, 2.5 to 5 cm. (1 to 2 in.) long and 5 mm. ($\frac{1}{5}$ in.) in diameter. The latter is *directed* downward and a little to the left in the right margin of the small omentum.

The common bile duct averages 7.5 to 8.5 cm. (3 to $3\frac{1}{2}$ in.) in *length* and 6 mm. ($\frac{1}{4}$ in.) in width. Its *course* lies nearly in the long axis of the body and continues that of the hepatic duct. The first or *supraduodenal portion*, about 2.5 cm. (1 in.) in length, extends down to the first portion of the duodenum in the right margin of the small omentum (hepatoduodenal ligament). This is the point of election for the removal of

Fig. 123



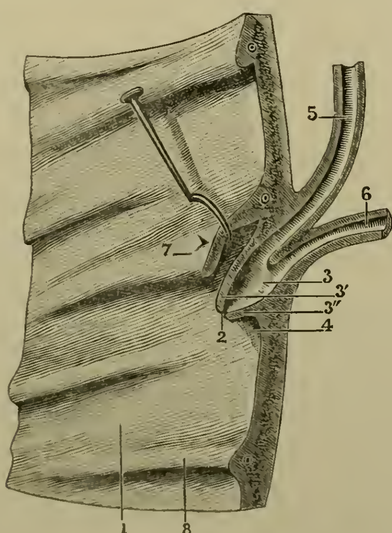
View of the abdominal viscera from behind, after removal of the spinal column and the whole of the posterior wall of the abdomen, the peritoneum being left. (After His' model.)

stones from the duct. The portal vein is behind it and to the left, the hepatic artery is to the left, but neither are near enough to make them liable to injury if care is taken. It lies in front of the foramen of Winslow and with one finger in the foramen and the thumb in front this portion can be palpated, but an enlarged lymph node in the small omentum should not be mistaken for a stone in the duct. The *second* or *retroduodenal portion*, nearly 2.5 cm. (1 in.) long, passes behind the duodenum, to the wall of which it may be closely applied. The vena cava lies postero-internally, the portal vein internally. The *third* or *pancreatic portion*, 20 to 25 mm. ($\frac{4}{5}$ to 1 in.) in length, passes between the head of the pancreas and the postero-internal aspect of the second

portion of the duodenum. In some cases (75 per cent., Bunger) it is enclosed in pancreatic tissue, so that in swelling of the latter it becomes compressed and obstructed, while in cases where it lies in a groove in the pancreas it may be pushed out of the way without being compressed. It passes obliquely through the wall of the duodenum for 18 mm. ($\frac{3}{4}$ in.), *opening* into the latter by a little round or oval orifice at the end of a papilla on its postero-internal aspect, about 8.5 cm. ($3\frac{2}{5}$ in.) from the pylorus, or 3.5 cm. $1\frac{2}{5}$ in.) below the crescentic fold in the lumen of the first bend of the duodenum. (See Duodenum.)

The **pancreatic duct** usually *joins* the common bile duct in the duodenal wall, and below their junction there is a little *dilatation* beneath the mucous membrane, **the ampulla of Vater.**

Fig. 124



1, Segment of second portion of duodenum, internal aspect; 2, orifice of ampulla of Vater; 3, its cavity, with its upper wall, 3′, and its lower wall, 3″; 5, common bile duct; 6, duct of Wirsung; 7, valvulæ conniventes overlying papilla.

The **papilla** (Figs. 123 and 124) contains the *narrowest part* of the common duct (1 to 2 mm.), hence stones are likely to be arrested just above it in the ampulla. The papilla is nearly covered by the first normal transverse valvulæ conniventes. Running down from this opening, and the rounded projection due to the ampulla, is a small longitudinal fold of mucous membrane. This appearance facilitates identification of the papilla, which is assisted if we can express a drop of bile and if we know just where to look for it. The oblique course of the duct through the duodenal wall and perhaps the valvular folds of its mucous membrane, described by Toldt, prevent the backward flow of the intestinal contents. The lower end of the common duct lies upon the vena cava, hence caution is required in incising the walls of the ducts.

The common duct may be *exposed at its lower end* by opening the second portion of the duodenum, in which it may be felt by the finger as a cord-like channel, along the postero-internal aspect. By slitting up the duct, as it lies in the walls of the gut, for 12 mm. ($\frac{1}{2}$ in.) from its opening, we can remove stones impacted in its lower end, as McBurney has shown. *Above this point* we can *expose the duct* by incising the peritoneum on the right of the duodenum, loosening the latter posteriorly and drawing it toward the median line. Still higher we can expose the duct by dissecting up the distal inch of the first portion of the duodenum from its posterior attachment and drawing it downward and inward. We may oftentimes force a stone along the duct into the supraduodenal portion from a lower point, incise the duct (*choledochotomy*), remove the stone, and then suture the duct or drain it.

All the *operations* on the gall-bladder and ducts are *performed in* the so-called *subhepatic space* (Morrison's pouch), *bounded by* the right lobe of the liver above, the transverse colon and mesocolon below, the parietes down to the iliac crest externally, and by the peritoneum covering the spine internally. The duodenum and right kidney occupy the floor of this space, and the pyloric end of the stomach encroaches upon the median side. This pouch can hold nearly a pint of fluid before it overflows over the pelvic brim or through the foramen of Winslow. It can be well drained through a lumbar incision. By pushing the liver up and retracting the transverse colon down, and perhaps pushing the stomach to the left, we get room for exploration and operation, though all the biliary passages lie at an uncomfortable depth. This may be partly obviated by placing a sandbag or firm cushion beneath the back behind the liver, and also by drawing the liver downward and rotating it upward and outward so as to turn the lower surface forward. As the result of inflammatory adhesion the subhepatic space may be obliterated, which greatly increases the difficulties of operation.

When a *stone* becomes *impacted* in one of the ducts the muscle fibers, which are mostly circular in the duct, make a violent spasmodic effort to dislodge it. This may be partly successful, the stone may pass on a little ways and again become impacted, and so on. Thus attacks of *hepatic or biliary colic* succeed one another until the stone is passed or becomes more firmly impacted. A stone impacted in the common duct may partly or wholly stop the flow of bile into the duodenum. In the latter case the ducts above the obstruction become distended, the stools become clay-colored, and the patient jaundiced. The gall-bladder, curiously enough, is rarely distended, but is contracted in nearly 90 per cent. of such cases of chronic common duct stone. The common and hepatic ducts are very extensile, so that they become much distended after obstruction has lasted for some time. Thus in most such cases the finger may be introduced through the duct up to the junction of the primary divisions and down to the obstruction. Obstruction may also follow pressure from without, as from a tumor of the head of the pancreas. Stenosis of the duct may also be due to inflammation of its mucosa.

Varieties.—The gall-bladder may be constricted transversely or longitudinally, it may be transposed, within the substance of the liver, or even absent, in which case the hepatic duct is usually dilated before opening into the intestine. The common duct has been congenitally absent, and yet life was possible for six months in two such cases.

The Pancreas.—The pancreas (Figs. 109, 114, 121, 122, and 123) is a *retroperitoneal* organ, and *lies* deeply in the epigastric and left hypochondriac regions, behind the stomach and the lesser peritoneal sac and between the duodenum on the right and the spleen on the left. Hence it is not easily accessible for surgical or diagnostic purposes. It crosses the median line in front of the first and second lumbar vertebræ, from 6 to 12.5 cm. ($2\frac{1}{2}$ to 5 in.) above the umbilicus. Although it has been ruptured, wounded, or even herniated (very rarely, in some cases of diaphragmatic hernia), these conditions almost never affect the pancreas alone, but only in connection with similar injuries of other neighboring viscera. It may sometimes be *felt* on deep pressure in emaciated subjects when the stomach and colon are empty.

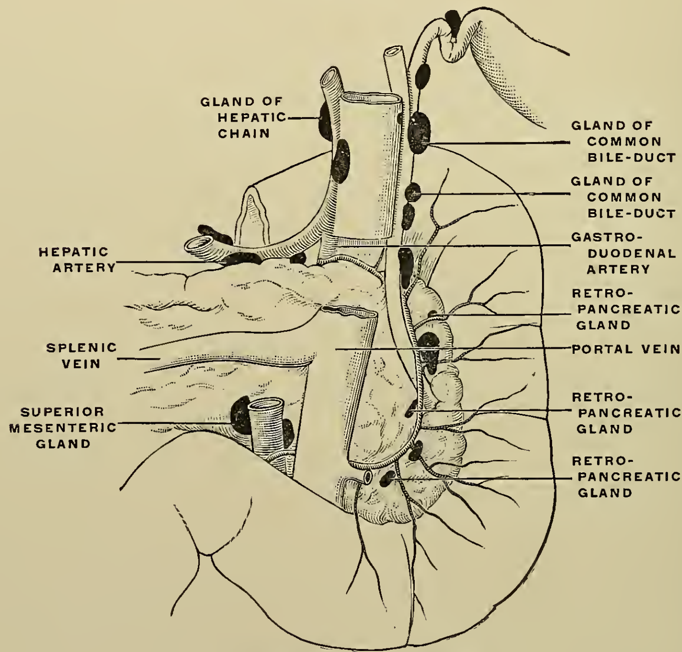
It *may be reached* by raising the omentum and transverse colon and dividing the transverse mesocolon, or by dividing the gastrocolic or the gastrohepatic ligaments, and then the peritoneum at the back of the lesser peritoneal sac. It may be drained posteriorly by an incision in the left costovertebral angle.

Although it has **relations** with many most important structures, many of these relations are of no surgical interest. The lower end of the common bile duct may lie in a groove, more often (62.5 to 75 per cent.) in a canal, in the head of the pancreas. Hence carcinoma or chronic inflammatory enlargement of the head of the pancreas may so press upon the duct as to partly or completely occlude it and cause persistent jaundice. This part of the pancreas has the vena cava, vena portæ, aorta, and superior mesenteric vessels, etc., behind it, so that removal of tumors, which are usually situated here, is almost impracticable unless they are encapsulated, although it has been done. The pancreas also lies in front of the left renal vein and the right renal vessels, and its tail is in front of the hilum and the middle or upper part of the left kidney. These relations are to be borne in mind in nephrectomy.

The pylorus of the full stomach lies in front of the neck of the pancreas. The splenic vein and artery lie in grooves respectively behind and above its upper border. The tail of the pancreas touches the spleen at its lower end and at the lower part of the gastric surface. From the relations of the pancreas we can understand the pressure symptoms of pancreatic tumor, according to the direction of its growth and the point of origin. In operations on the pylorus or the spleen it is important not to wound the pancreas or to include it in the ligature. Such an injury to an adherent pancreas in pylorectomy for pyloric cancer greatly increases the mortality. Also the secretion of the pancreas may perhaps interfere with the healing of the wound by dissolving the cicatrix and lead to an obstinate fistula. Perforating ulcers of the rear wall of the stomach may result in adhesion of the latter to the pancreas, or, rarely, in abscess of

the pancreas. A biliary calculus lodged just beyond the ampulla of Vater, or in the papilla, obstructs the pancreatic duct, which usually joins the common bile duct in the duodenal wall just above the ampulla. Opie has shown that a small calculus obstructing the outlet of the ampulla converts the two ducts into a continuous channel permitting the entrance of infectious bile into the pancreatic duct and thus causing acute pancreatitis. Chronic pancreatitis is also very often associated with the presence of gallstones. The occlusion of both ducts by a larger stone, just above or filling the ampulla, affords less danger to the pancreas on account of the accessory *duct of* Santorini. This is present

Fig. 125



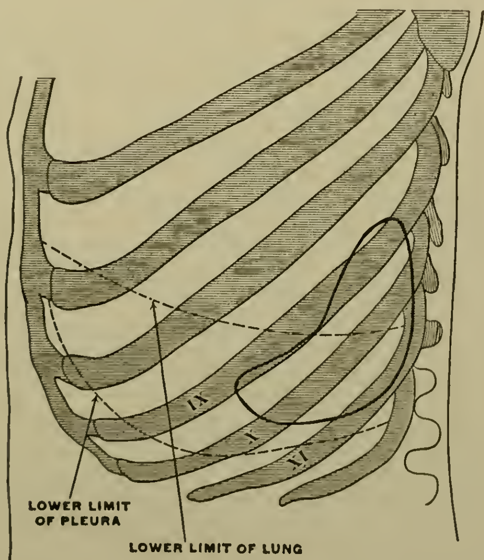
Retropancreatic lymph nodes.

in all cases and opens into the duodenum separately 2 cm. ($\frac{3}{4}$ in.) above the papilla. In 12 per cent. of cases it is the main outlet of the pancreas, and in 54 per cent. it may act as a substitute for the duct of Wirsung, if the outlet of that is closed, by communicating with it above. The entire pancreatic secretion is conveyed by the duct of Wirsung in 83 per cent. of cases. Calculi may form in these ducts and give rise to colic resembling gallstone colic.

Cysts occasionally occur in the pancreas, the result of obstruction of the duct, injury or other causes. Such cysts appear in the epigastrium above the umbilicus, usually below the stomach, which is pushed up, and above the transverse colon. In other cases they appear above the stom-

ach, pushing it down, while occasionally it pushes forward between the layers of the transverse mesocolon or bulges the latter downward. They require opening and drainage of the fluid, which may be under great pressure. Acute inflammation of the pancreas (**pancreatitis**) may involve hemorrhage, necrosis or abscess of the pancreas, fat necrosis or general peritonitis, and demands operation. If in case of occlusion of the pancreatic duct, acute inflammation, injury, etc., the fat-splitting ferment of the pancreatic juice escapes into the retroperitoneal tissue or on the surface of the peritoneum, it causes fat necrosis. Chronic pancreatitis may obstruct the common bile duct by pressure and also calls for operative treatment, by indirect drainage by cholecystostomy. In not a few cases accessory pancreases are found in the wall of the stomach or small

Fig. 126



Outline of lower half of bony thorax, showing the position of the spleen. (Merkel.)

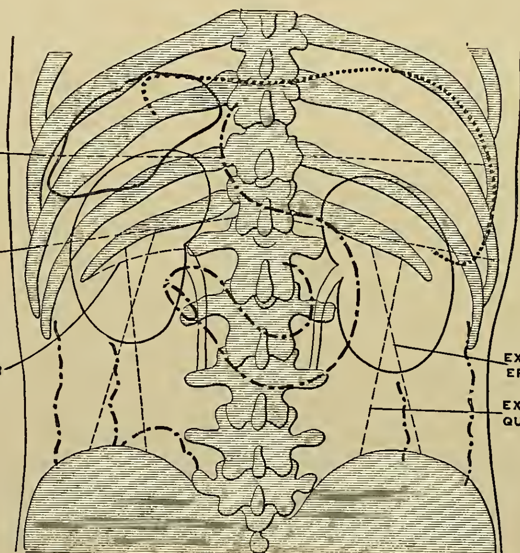
intestine, especially the duodenum, and may be mistaken for newgrowths. Several cases are recorded of an annular growth forming a ring around the second part of the duodenum, which it may constrict so as to cause dilatation of the stomach and the duodenum above it.

The Spleen.—**Position** (Figs. 109, 125, 126, and 127).—The spleen, the largest and most important of the *ductless glands*, lies in the dorsal part of the left hypochondriac and epigastric regions, between the concavity of the diaphragm behind and to the left, the fundus of the stomach in front and to the right, the left kidney and the splenic flexure of the colon internally and below. Its *long axis* corresponds to that of the tenth rib, and it extends between the eighth and eleventh ribs. The *upper or larger end* extends to within 3.5 to 5 cm. (1½ to 2 in.) of the median line,

or within 2.5 cm. (1 in.) of the vertebral column, and sometimes touches the latter. It is on a level with the tenth thoracic vertebra or the ninth thoracic spine. Its *lower end,* which lies farther downward, outward, and forward on a level with the first lumbar spine, nearly reaches the mid-axillary line, but normally does not extend beyond the left costoclavicular line (*i. e.,* from the left sternoclavicular joint to the tip of the left eleventh rib).

The spleen, therefore, lies under cover of the bony thorax and *cannot be palpated* when normal. Its *position is affected by* respiration, though not so much as that of the liver, for the diaphragm exercises less influence upon it. It sinks somewhat in inspiration, pleural effusions, and

Fig. 127



Outline of the abdominal viscera from behind, showing their relation to one another, the lower ribs, and the vertebrae: ————, kidneys; ————, spleen; ...., liver; —·—·—·—, duodenal loop and colon. (Merkel.)

emphysema; it rises in expiration, and is pushed up by ascites and abdominal tumors. When much enlarged it displaces the heart and left lung upward, causing palpitation and shortness of breath.

The spleen is **held in position by** peritoneal folds containing some fibrous-tissue strands. The lienorenal or lienophrenic ligament is a double fold of peritoneum which passes from the abdominal wall at the tail of the pancreas or the front of the left kidney to the hilum of the spleen and encloses the splenic vessels. An inconstant fold, belonging to the upper end of this, which extends from the left crus of the diaphragm, is known as the suspensory ligament of the spleen. The *phrenocolic ligament* (sustentaculum lienis), passing from the diaphragm, opposite the free ends of the tenth and eleventh ribs, to the splenic flexure of the

colon, forms a shelf or pocket for the spleen, especially in the newborn, and holds it up by supporting the colon on which it rests. If the latter ligament becomes relaxed, the spleen is *displaced* downward and lies more vertically. It is also supported by intra-abdominal pressure. Rarely the spleen is found low down in the abdomen or even in the pelvis. Such a "*wandering spleen*" is liable to atrophy from a torsion of the vessels in the lengthened pedicle, and it may cause so much pain from stretching of the vessels and nerves as to require removal.

The *gastrosplenic omentum* affords but little fixation to the spleen, more to the fundus of the empty stomach. When the stomach is empty this omentum lies transversely, while the full stomach separates the two layers to cover its distended fundus. Thus the full stomach comes in direct relation with the spleen. When the stomach is distended the spleen becomes more horizontal, and vice versa.

As to **size**, the spleen varies more than any other organ. Its *normal average* in the adult is about 12.5 cm. (5 in.) in length, 7.5 cm. (3 in.) in width, and 3 cm. ($1\frac{1}{4}$ in.) in thickness; also 170 to 195 grams in *weight* in the cadaver, and about one-sixth more when filled with blood. It is relatively large in childhood, and atrophies in old age. It is *enlarged* during digestion, in cases of congestion of the portal vein, in malarial poisoning, in one form of leukemia, and in infectious diseases. It may attain such size as to reach the pelvis and nearly fill the whole abdomen, so as to be mistaken for an ovarian or uterine tumor, but unlike tumors of the kidney it is not covered in front by intestines. Its weight may equal 20 pounds or more. In the child the enlarged spleen, in its earlier stages, is said to encroach upon the thoracic cavity more than in the adult, owing to the firmer support of the phrenocolic ligament in the young. More rarely the spleen is enlarged on account of abscess, cysts (especially hydatids), and malignant tumors. In cases of enlargement its limits may be determined by palpation even better than by percussion. The normal *notching* of its *sharp anterior border* helps to identify the spleen when enlarged below the costal margin. There are not infrequently *supernumerary spleens*, partly or entirely detached from the mother organ, and in the latter case usually situated in the gastrosplenic or great omentum, or in the transverse mesocolon. On the other hand, the spleen may be congenitally wanting.

Owing to its soft **consistence** it is very *friable*, and therefore liable to *rupture*. But this accident is not common with the normal spleen, owing to the protection afforded by its position and relations and the fact that it is swung up by and rests upon elastic peritoneal folds. When *enlarged* the spleen is *more readily ruptured*, often by quite insignificant violence without trace of injury externally, and even by muscular violence, of which several cases are recorded. The spleen may be lacerated in severe fractures of the left ninth, tenth, or eleventh ribs, by the broken end of a rib driven through the diaphragm, or directly by the violence which produced the fracture. Owing to the extreme *vascularity* of the spleen its rupture is often fatal from hemorrhage if not operated upon. The spontaneous recovery of cases of limited wounds and gunshot

injuries of the spleen is aided by the contraction of the muscle fibers in its capsule, which narrows the opening and favors the arrest of hemorrhage by coagulation of the blood.

Relations (Figs. 114, 121, and 123).—The convex *dorsal or phrenic surface, directed* backward, upward, and to the left, is *in contact with* the diaphragm. It is separated from the parietes at its lower end by the diaphragm, higher up by the diaphragm and the costophrenic sinus of the pleura, and above by the diaphragm and the lower edge of the lung. These relationships explain the cases where wounds of the spleen are combined with those of the lung and pleura and the rare cases where abscess of the spleen has perforated through the diaphragm into the left pleural cavity. The concave *gastric surface, directed* forward and inward, is *in contact with* the fundus of the stomach when the latter is full, but not when it is empty and contracted. The tail of the pancreas reaches its lower end. The upper end and the upper half of the outer border of the left kidney is in contact with the *renal surface,* which *looks* inward and downward. At the *lower and outer end* of the spleen is a *triangular area* (basal surface) which rests upon the splenic flexure of the colon and the phrenocolic ligament.

These *relations explain the difficulty in percussing* the normal or slightly enlarged spleen. Its upper end, above the tenth rib, is overlapped by the lung and covered by the thick muscles of the back. Below the lung it rests against the kidney and colon, so that its limit cannot be defined by percussion, especially if the colon is filled with fecal masses. The difficulty is still further increased if the stomach is filled with food. The *lower and outer end* is the *only part determinable by percussion,* and even here fecal masses in the colon may interfere. The area of splenic dulness may disappear in emphysema and pleuritic effusions; and it varies in respiration as well as with any change in position or size of the organ.

The spleen is entirely *covered with peritoneum* except about the hilum, a row of depressions, on the gastric surface just in front of the inner border, where the vessels enter or emerge between the two layers of peritoneum forming the gastrosplenic omentum. The latter, with the contained vessels, forms the *pedicle* which requires to be carefully ligated in extirpation of the spleen (*splenectomy*).

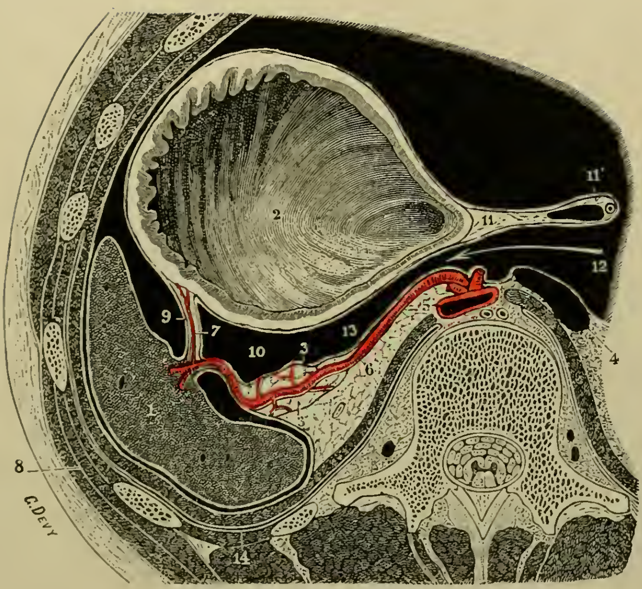
Of the **vessels,** the *tortuous artery* is very large for the size of the spleen and renders it a very vascular organ. It also sends branches to the pancreas and to the fundus of the stomach (vasa brevia in the gastrosplenic omentum). The **splenic vein** goes to form the portal vein, and is double the size of the artery. It lies below the artery and runs a straighter course. The *lymphatics* collect in nodes at the tail of the pancreas.

Although the spleen is rich in bloodvessels, it is poor as to *nerve supply,* which comes from the solar plexus.

Extirpation of the spleen (*splenectomy*) is indicated and has been done for wounds and ruptures, cysts and abscess, simple and malarial hypertrophies, and "wandering spleen." For the latter condition *splenopexy* has also been advised and performed by stitching the spleen in

PLATE XXXV

FIG. 128



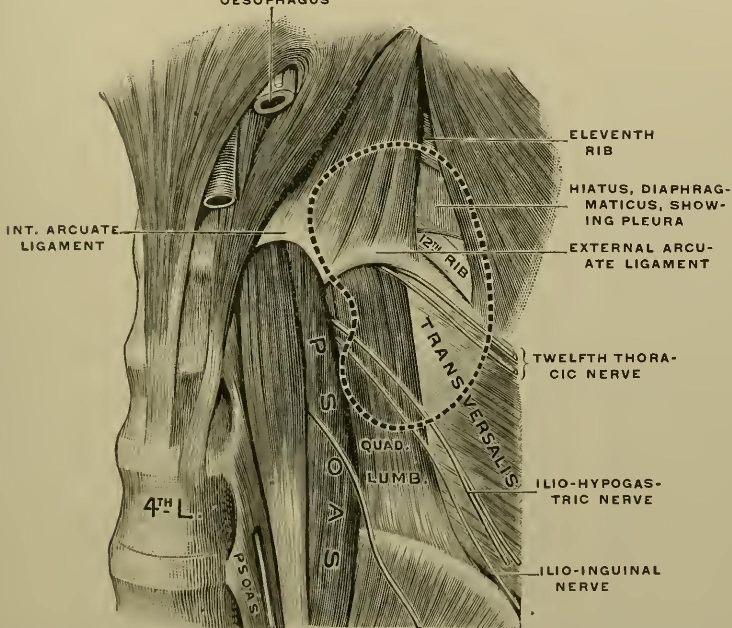
Horizontal Section Passing through Hilum of the Spleen, to show the Relations of this organ to the peritoneum. (Schematic.)

1. Spleen.
2. Stomach.
3. Tail of pancreas.
4. Inferior cava.
5. Aorta.
6. Splenic artery.
8. Thoracic abdominal walls.
9. Gastrosplenic omentum containing vasa brevia.
11. Small omentum.
11'. Its free right border.
12. Foramen of Winslow.
13. Lesser peritoneal sac.
14. Left pleural sinus.

place and forming a new peritoneal shelf for it. In splenectomy a *free incision* is made along the left costal border, or sometimes in the median line or in the left semilunar line. The most important and difficult feature is securing and ligating the pedicle, the gastrosplenic omentum and lienorenal ligament, with the very large vessels contained. If too much traction is made there is danger of tearing these vessels, especially the splenic vein.

The Kidneys.—Position (Figs. 109, 127, 129, 130, and 131).—The kidneys lie *retroperitoneally* and are deeply placed, one on either side of the spine, so that they cannot usually be palpated when normal in

Fig. 129



Position of the kidney with reference to the posterior abdominal wall. The dotted line represents the position of the left kidney. (Testut.)

size and position, except the lower end of the right kidney in some thin patients. They *approach the surface* most nearly below the twelfth rib and to the outer side of the erector spinæ muscle. When palpable they may be *best felt* from in front just below the costal margin and external to the rectus muscle, while the other hand presses forward from behind, below the last rib.

The vertical line perpendicular to the middle of Poupart's ligament, which marks off the regions of the abdomen, cuts the kidney longitudinally, so that one-third of it lies to the outer side and two-thirds to the inner side. The infracostal plane, connecting the lowest points of the tenth costal cartilages, cuts the lower ends of the kidneys, though it is

not infrequently above the lower end of the left kidney. Hence the kidneys are *found in the following regions:* epigastric, hypochondriac, umbilical, and lumbar, but mainly in the two former and little or none in the lumbar region, where they are often incorrectly thought of as being. In the *female* and the child they are, as a rule, slightly *lower,* often reaching the level of the iliac crest. In the male also they are not infrequently lower than normal. In most cases the *right kidney* is about 12 mm. ($\frac{1}{2}$ in.) *lower* than the left, especially at the upper end, but exceptions are common. With these modifications in mind, we may say that the kidneys *correspond to* the last thoracic and the first two or three lumbar vertebræ. The left kidney extends from the level of the lower end of the eleventh thoracic spine to the third lumbar spine.

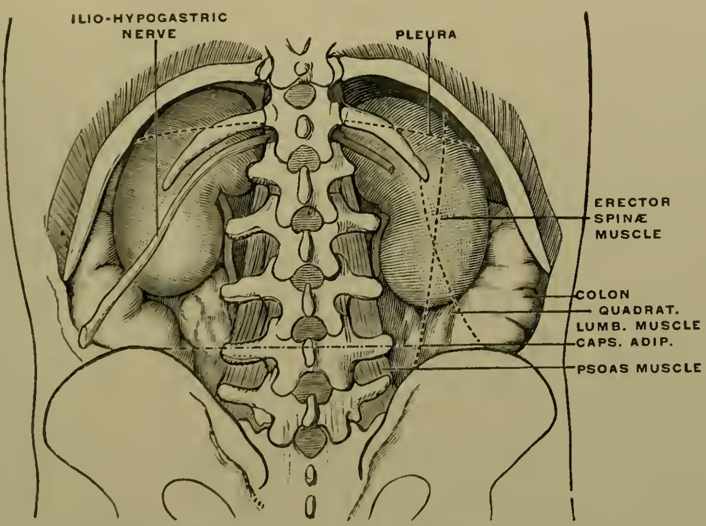
The **position** of the kidney may be *indicated posteriorly* by a parallelogram whose upper and lower ends are drawn horizontally outward from the two latter points, about 10 or 11.5 cm. (4 or $4\frac{1}{2}$ in.) apart, while the sides are drawn vertically 2.5 cm. (1 in.) and 9.5 cm. ($3\frac{3}{4}$ in.) from the spines (Morris). The *outer border,* therefore, reaches a point 8.5 to 10 cm. ($3\frac{1}{2}$ to 4 in.) from the lumbar spines. The *twelfth rib* crosses the position of the kidney in such a way that one-third or more of the organ is above it, under cover of the thoracic wall. This rib is sometimes *resected* in operations upon the kidneys in order to gain more room, and with care it may be done without risk to the pleura. But in one case with rudimentary twelfth rib, the eleventh rib was removed for the twelfth, the pleura opened, and death resulted. The *eleventh rib* overlaps the upper pole of the left kidney, and the tips of the transverse processes of the first and second and often the third lumbar vertebræ overlap the mesial border of both kidneys. The *lower end* of the right kidney is, on the average, 2.5 to 3.5 cm. (1 to $1\frac{1}{2}$ in.) above the iliac crest behind and the level of the umbilicus in front, hence the kidneys lie higher than often supposed.

In front the *upper ends* of the kidneys about *correspond to* the interchondral articulation of the sixth and seventh costal cartilages, and they extend downward from here 10 or 11.5 cm. (4 or $4\frac{1}{2}$ in.), *i. e.,* to 2.5 cm. or so above the umbilicus. The *shortest distance between* the two kidneys above is about 6 cm. ($2\frac{1}{2}$ in.). The *hilum* is about 5 cm. from the median line and opposite the first lumbar spine. Owing to the oblique position of the kidneys, the axis sloping downward and outward, the *lower pole* of the organ, or the centre of the lower end, is 1 to 2.5 cm. farther from the median line than the upper pole, which is 5 cm. (2 in.) from it. The *inner border* of the right kidney lies very close to the vena cava, that of the left kidney 2.5 cm. (1 in.) or more from the aorta.

The slight *downward movement* (12 mm. [$\frac{1}{2}$ in.], Holden) of the kidneys *in inspiration* or their lower position in accumulations in the pleura are accounted for by the relation of the kidneys to the diaphragm and to the organs like the spleen and liver, which move with it. The kidneys also lie slightly lower (about 1 to 1.5 cm.) in the standing than in the reclining position.

Posterior Relations (Figs. 129 and 130).—The kidneys *lie upon* the diaphragm above, and the quadratus lumborum, transversalis, and the outer border of the psoas below, the muscles being covered by their respective fasciæ. Intervening *between the quadratus muscle and the kidney* are the last thoracic, iliohypogastric, and ilio-inguinal nerves and the first lumbar vessels, all of which pass obliquely outward and downward, and may be met with in exposing the kidneys from behind. The *last thoracic nerve* indicates the *lower end of the diaphragm*, above which it is not safe to incise. The area of contact with the diaphragm is larger on the left than on the right side, owing to the higher position of the left kidney. But on both sides it is of great importance, as the kidney is here in close relation to

Fig. 130



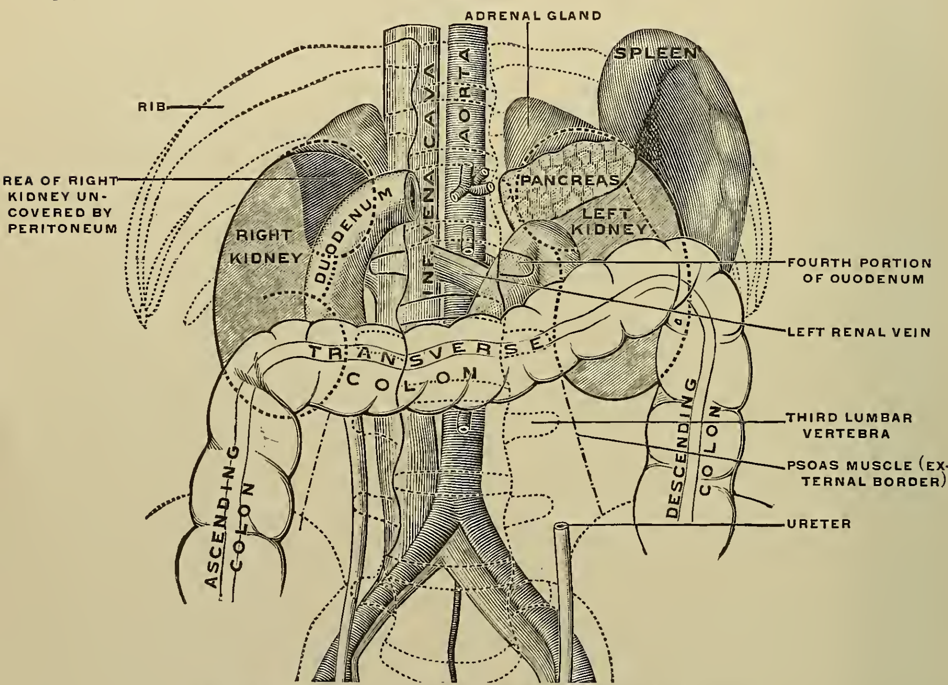
Topography of the kidney seen from behind. The outlines of the quadratus lumborum and the erector spinæ are shown. The portion of the psoas arising from the transverse processes have been removed. The right twelfth rib is shorter than usual.

the pleura, whose lower limit extends nearly horizontally from the lower border of the twelfth thoracic vertebra, meeting the twelfth rib about 8.7 cm. (3½ in.) from the median line and the eleventh rib about 5 cm. (2 in.) farther laterally. If a marked *hiatus diaphragmaticus* exists above the lig. arcuatum ext. between the vertebral and costal portions of the diaphragm, the kidney may come in *contact with the subpleural tissue.* The *relationship of the kidney and pleura* explains (1) the frequency of perforation of perinephritic abscesses into the pleura, especially on the left side, a serious complication, and (2) the danger of opening the pleura in operating upon the kidney, especially if the last rib should be rudimentary and the eleventh rib be mistaken for it, from failure to count the ribs. As a rule, the *incision* may be safely carried just below the lower border of the twelfth rib, but it must be remembered

that sometimes that part of the pleura which extends below the twelfth rib reaches beyond the lateral margin of the quadratus lumborum, under otherwise normal conditions. A thirteenth rib would contract the space available for the lumbar approach to the kidneys.

The Anterior Relations (Figs. 114, 121, 123, and 131).—The anterior relations of the two kidneys are different. In front of the **right kidney** is the liver (renal impression) in the upper half, the ascending colon in the lower half, and the second portion of the duodenum along the inner margin. The following viscera lie in front of the **left kidney** in the positions indicated: The stomach in the upper third, the splenic vessels and

Fig. 131



Relations of the anterior surface of the kidney (semidiagrammatic).

pancreas in the middle third, and the descending colon in the outer part of lower third, while along the upper half of the outer border lies the spleen. *Abscess* of or about the kidney may involve the other organs in contact, such as the liver, spleen, or pancreas; or perforate and open into the colon, duodenum, or stomach. The above relations are also important to remember in nephrectomy. In the case of *tumors* or other enlargements of the kidney the resonant colon is pushed forward in front of them, hence there is tympanitic resonance in front. Inflammatory swellings of the kidney have but little movement with respiration, tumors may move considerably, and they are rounded and not notched like the anterior margin of the spleen. They often maintain the shape of the

kidney and are usually separated from the liver dulness by a resonant area. If large, they may compress the spermatic vein and cause varicocele. The position of the kidneys under the spleen or liver explains how enlargement or displacement of these organs displace the kidneys downward.

Relations of the Kidney to the Peritoneum.—The above viscera in relation to the anterior surface of the kidney, with the exception of the liver and stomach, intervene between the kidney and the peritoneum, so that the latter covers only a limited area of the anterior renal surface. This area is somewhat greater in the right kidney than in the left. The peritoneum covering the left kidney is derived from that of both the lesser and greater peritoneal sacs. The peritoneal covering is readily stripped from the kidney. According to Lange, the distance between the lateral edge of the quadratus muscle, internally, and the point where the peritoneum, external to the kidney, touches the parietes, is considerable, but is less on the left side by at least 1 cm. It is in this space that we expose the kidney by the lumbar incision. The peritoneum forms a complete covering, *mesonephron,* in the congenital variety of floating kidney. The position of the kidney behind the peritoneum allows us to *reach and operate* upon it by a *lumbar incision without opening the peritoneum,* and explains why rupture is not so serious as with the liver, spleen, and intestines, as the extravasation is usually extraperitoneal. *Wounds* of the kidney from behind may readily occur without injury to the peritoneum. Although the kidney is quite well protected by thick muscles behind, its consistence allows it to be not uncommonly *ruptured* by external violence (39 per cent. of visceral lesions). The rupture has been shown to be due to a force acting through the full vessels and pelvis. This causes the kidney to burst along a plane which usually passes through the hilum and in line with the tubules, which are transverse. The rupture may open into the pelvis only, on the surface only, or in both directions (complete), and it may occasionally involve the peritoneal covering (transperitoneal), especially in children under ten years, who lack the perirenal fat. As the kidney lies at the angle of the bend when the back is bent far forward, it may be caught and squeezed between the lower ribs and the ilium, or ruptured by a heavy weight falling upon the bent back, while the kidney is caught in the bend. In renal injuries the kidney is usually compressed between the lower ribs and the spine.

Fixation of the Kidneys.—The fixation of the kidneys is *due to* the embedding *fat* (tunica adiposa), a part of the subperitoneal connective tissue, to the renal vessels, to the attachment to the contiguous viscera, to the narrowing of the renal fossæ below, and to the overlying parietal peritoneum, which is connected with the kidney and its "**fatty capsule.**" The latter, usually scant at birth, increases about puberty and in adult life, and is found most abundantly along the borders and posteriorly. Near the kidney this may assume the character of a distinct fascia (*perirenal fascia*), which, passing behind and in front of the kidney, is attached to the fibrous capsule and to the transversalis fascia, spine, diaphragm,

etc., with fatty tissue on both sides of it. When this fatty tissue is absorbed, owing to emaciation from any cause, the kidney loses its support and **may become movable** from slight causes: tight lacing, enlarged liver, accumulations above the diaphragm, a chronic cough, external violence, traction of the ureter, colon, or duodenum (ptosis of other viscera), and increased weight of the kidney. As the kidney is also *supported by intra-abdominal pressure,* the exciting cause of a movable kidney may be a relaxation of the abdominal walls, as the result of labor, removal of tumors, ascites, general muscular weakness, etc. Hence we can understand why movable kidney is so much *more common in women* (80 per cent. of cases) than in men. It is also *more common on the right side* (90 to 95 per cent. of cases) than on the left, a fact probably due largely to the liver, pressed down upon it by tight lacing and hammering on the kidney with each inspiration, as well as to the firmer fixation of the left kidney. The excursion of a movable kidney is limited by the length of its vessels. These may become lengthened and allow it to slip down far enough behind the peritoneum on deep inspiration, so that (1st degree) its lower pole is palpable, (2d) the entire kidney is palpable, and (3d) it may be retained by the fingers below the costal margin in front. The symptoms of a movable kidney are due largely to the *traction* upon its nerves, its vessels, the ureter (kinking it), and the gastro-intestinal tract, especially the duodenum, through direct attachment or through the peritoneum. In *floating kidney* the *mesonephron,* or peritoneal pedicle containing the unduly long bloodvessels, allows a wider excursion, to the anterior abdominal wall, the iliac fossa, or even to the pelvic cavity. The longer the pedicle the greater the danger of its torsion and the resulting atrophy, gangrene, or hydronephrosis of the kidney. Movable kidneys, when the symptoms demand it, may be fixed by suture and other means, through a lumbar incision.

It is through this *fatty capsule* of a canary-yellow color, which, if excessive, protrudes hernia-like into the incision, that we work our way by blunt dissection in order to expose the kidney through the lumbar incision. The looseness of this tissue permits the ready enucleation of the kidney, except in cases where it has become adherent to the kidney as the result of inflammation. If scanty, the fatty capsule often appears as a fascial membrane, which may be mistaken for peritoneum or transversalis fascia. Again, it is in this tissue that **perinephritic abscesses** develop, from disease of the kidney or neighboring parts or from injury. The spread of such abscesses we can understand from the looseness of this tissue and its continuity with the adjoining subperitoneal connective tissue. As such abscesses are in contact with the diaphragm above, they are not unlikely to perforate this and break into the pleura. Curiously enough, they, as well as abscesses of the kidney, rarely perforate the peritoneum. For further accounts of their course, see Posterior Relations of the Kidney (p. 381) and Abdominal Walls, Lumbar Region (p. 314).

Misplacements and Varieties of the Kidneys.—One, more often the left, less often both kidneys, may be congenitally *misplaced.* A misplaced kidney is often misshapen, lobulated, as in the fetus, or hourglass,

horseshoe, or disk-shaped, etc. Congenital displacement is downward, as a rule, so that the organ lies in the iliac fossa, on the pelvic brim, or even in the pelvis. It may give rise to serious error in diagnosis or treatment. One kidney is sometimes much *smaller* than the other (1 in 138), or both may be fused together as a *single "disk-like" mass* (1 in 12,000 cases), with one or two pelves and ureters, or more often as a *horseshoe kidney* (1 in 1000 cases) joined at their lower ends across the median line by kidney or connective tissue. When joined by connective tissue this is no bar to operation, even to removal of half of the kidney. Rarely there may be either one kidney or extreme congenital atrophy of the other one (1 in 2650 cases) and extremely rarely three kidneys. The presence of an abnormally placed renal mass should be so suggestive of a single kidney as to prevent nephrectomy until a second kidney has been found present (Morris).

The Hilum.—The hilum of the kidney *looks* forward, more or less inward, and slightly downward. Its posterior lip is thick and nearer to the median line. Of the principal structures which enter or emerge from the sinus at this slit-like aperture, the vein is in front, the artery behind it, and the pelvis of the ureter the most posterior and inferior. Hence the *pelvis* is *most accessible* to exposure *from behind.*

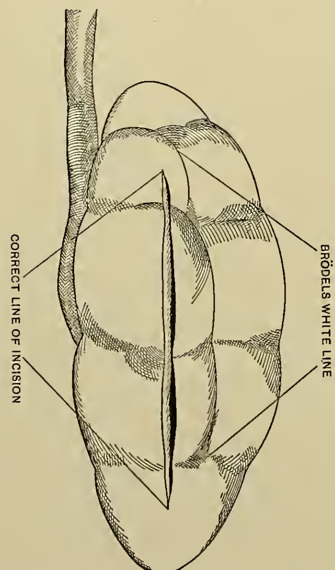
The Vessels.—The vessels form the important element of the *pedicle* in nephrectomy, and are to be *ligated* together or separately and apart from the ureter if possible. In this connection it is well to remember that the left artery and right vein are shorter than their fellows, and the shortness of the right renal vein sometimes embarrasses the operator in a nephrectomy or other operation on the right kidney, and may make it difficult or impossible to deliver the kidney onto the loin, through a lumbar incision. The renal arteries, about the size of the brachial, divide into about three large branches before entering the hilum, and in nearly 50 per cent. of cases they present *irregularities in number, place of entry,* etc. Frequently one or more *additional arteries* are given off from the aorta, or the neighboring branches, and pass to the hilum, the anterior surface, or either end of the kidney, most often to the lower end (inferior renal artery).

The *veins* are less often, but not infrequently, *irregular.* They may accompany the additional arteries at either end of the kidney, or a branch may be found entering the hilum, with a branch of the artery, *behind the pelvis.* There would be danger of wounding the latter vessels in opening the pelvis from behind for exploration or the extraction of a calculus. The frequency of the above irregularities in the vessels should be borne in mind in a nephrectomy, for several cases are recorded where supernumerary renal vessels, not entering at the hilum, have given rise to serious, if not fatal, hemorrhage.

Owing to the deep position of the kidneys, they and their *vessels* are liable to be *pressed upon* in the supine position by the viscera as well as by tumors or the gravid uterus. Hence their secretory functions are probably influenced by changes in posture, so that the latter might be utilized in therapeutics. *Congestion* of the renal vessels may be due

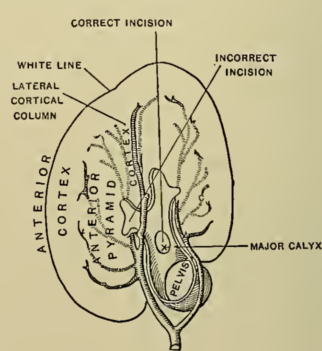
to other causes than direct pressure, *i. e.*, impeded circulation through the lungs or heart, inflammation, etc. Long-continued congestion begets increase of the interstitial fibrous tissue, the contraction of which later on produces *cirrhotic or atrophic kidney,* just as similar conditions in the liver produce cirrhosis of the liver. Owing to the *anastomosis* between the small vessels of the surface of the kidney and the branches of the lumbar vessels, bloodletting, cupping, or counterirritation in the loins may relieve congestion of the kidney. In order to improve this anastomosis, decapsulation has been performed in chronic nephritis. In time, however, with the contraction of the new adhesions, the temporary improvement disappears. The *lymphatics* (both superficial and

Fig. 132



Lateral view of the kidney with its pelvis distended, showing the correct line of incision through the lateral portion of the posterior pyramids, parallel to and 1 cm. from the white line.

Fig. 133



Transverse section of the kidney, showing the two arterial systems, the larger anterior and the smaller posterior. The line of correct incision passes through into the pelvis between these two vascular trees.

deep) accompany the bloodvessels, especially the vein, and enter the nodes lying on the corresponding side or in front of the aorta, and below rather than above the renal vessels. The superficial subcapsular lymphatics connect freely with the lymphatics of the perirenal adipose tissue.

Nerves.—The nerves of the kidney come from the *renal plexus* which is *derived from* the solar and aortic plexuses and the lesser splanchnic nerves. The *communication* between the renal and spermatic plexuses accounts for the radiation of the pain of a renal colic to the testicle and the peculiar testicular nausea from pressure upon a movable kidney, etc. The nausea and vomiting, and other symptoms of intestinal colic, or

the rectal and vesical tenesmus, sometimes present in a renal colic or a movable kidney (Dittel's crises), are accounted for by the relation of the nerves of the kidney with the ganglia supplying the intestines and bladder. On account of the association between the renal plexus and the upper lumbar nerves, pain in renal colic may radiate along the latter and be referred to the outer border of the right rectus in the spino-umbilical line, simulating appendicitis, or the testicle may be drawn up by the cremaster. On the other hand, caries of the upper lumbar vertebræ may be mistaken for renal calculus, on account of the location of the pain. The most sensitive parts of the kidney are the pelvis and the capsule, hence renal pain may depend not only upon infection, irritation of a calculus, etc., but upon tension, the relief of which, and often of congestion, follows splitting the capsule with or without puncture of the kidney. Occasional cures of various forms of nephritis have been obtained in this way.

The kidney is surrounded by a thin but strong **fibrous capsule**. In the healthy condition this capsule can be *peeled off* from the kidney, leaving its *surface smooth*, for the two are only connected by a delicate reticulum of fibrous tissue and minute vessels. In a cirrhotic kidney, and some other lesions of the kidney, this reticulum is thickened so that it is difficult to peel off the capsule, and the renal surface is left very rough when it is so removed. Hence these facts are made use of in autopsies as indicating a healthy or a diseased kidney. In some cases of nephrectomy, when it is difficult to shell out the kidney from its fatty capsule, owing to previous inflammation, it may be easier to remove it from within its fibrous capsule, though the hemorrhage, from oozing of the small vessels, is more profuse.

Operations on the Kidney.—The kidney is incised (*nephrotomy*) along its outer border for exploration, drainage, relief of tension, or removal of a calculus (*nephrolithotomy*). In incision of the kidney it is to be borne in mind that the blood supply of most kidneys is divisible into two systems completely separated by the renal pelvis, an anterior system carrying three-fourths of the blood and a posterior system carrying one-fourth. The line of safety for incision is the longitudinal line between these two systems, along the lateral border, 1 cm. posterior to the white line of Brödel, which is noticed when the pelvis is distended. By palpating at the hilum we can feel on which side are the lesser number of vessels, usually posteriorly (Figs. 132 and 133). The entire organ may be removed (*nephrectomy*), or it may be secured in its normal position by suturing (*nephrorrhaphy*) when movable.

The kidney is *exposed* for these purposes by a vertical or, preferably, an obliquely transverse lumbar *incision* in the iliocostal space between the lower ribs and the iliac crest. To gain additional room, the incision may be prolonged forward as far as the rectus muscle, or forward and upward toward the umbilicus from just above the anterior iliac spine, or enlarged by making a flap. In nephrectomy for a very large tumor, some prefer the transperitoneal method, incising, as a rule, in the corresponding semilunar line. In the latter operation the kidney should be reached from the outer side of the colon to avoid the colic vessels.

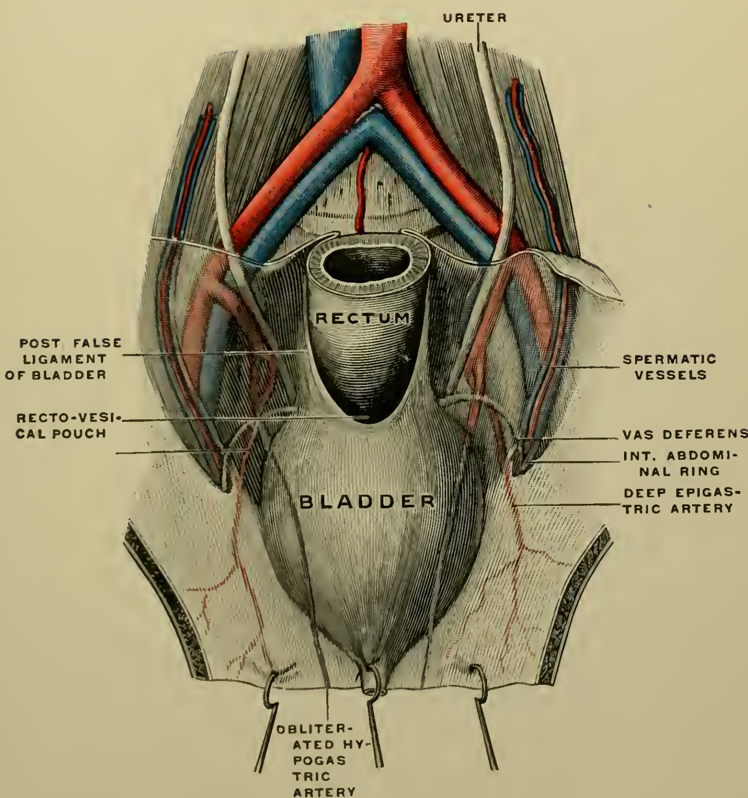
For the details of the lumbar incision, see Lumbar Region, Posterior Abdominal Wall, page 315.

The Ureters.—The ureters are about 27 to 30 cm. (11 to 12 in.) *long* in the male. The *diameter* is not uniform, but varies between 3.2 and 8 mm., and between its narrow points it shows spindle-shaped enlargements. *Above* they spring from a funnel-shaped enlargement, **the pelvis**, which, passing out at the back of the hilum, where it may be reached and opened, narrows as it descends until it attains the cylindrical character of the ureter opposite the lower end of the kidney. A constriction about 7 cm. ($2\frac{3}{4}$ in.) below the kidney forms the narrowest point of the ureter. The second constriction is at the bend at the pelvic brim. The third constriction, and next to narrowest point, is at its lower opening and in its passage through the bladder wall, hence calculi which have passed the other constrictions are likely to be arrested here, where they can be readily felt through the vagina in the female. In cases of gradual dilatation, the ureters are capable of great *distention*, to the size of the thumb or even that of the small intestine. This is not due to a backward flow from the bladder, but to an obstruction in the lower urinary passages, causing distention and perhaps frequent contraction of the bladder, thus preventing the emptying of the ureter, for the ureters cannot be emptied when the walls of the bladder contract or its cavity is too distended. The *oblique passage* of the ureter *through the bladder* walls downward and inward for 12 to 18 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) *acts as a valve,* preventing reflux into the ureter, so that the fuller the bladder the more tightly is the ureter mouth closed.

Course.—The ureters lie about 9 to 11 cm. ($3\frac{1}{2}$ to $4\frac{1}{2}$ in.) apart at their commencement and, converging slightly as they descend in the umbilical (not the lumbar) region, they are about 6.7 to 8.5 cm. ($2\frac{3}{4}$ to $3\frac{1}{2}$ in.) apart as they cross the pelvic brim, near the sacro-iliac joint, to enter the pelvis. They then diverge, following the curve of the lateral pelvic wall to the level of the ischial spine. In this part of their course they lie in front of the internal iliac arteries and cross the obturator vessels and nerves. They then turn inward and *in the male* lie in the parietal attachments of the posterior false ligaments of the bladder, in which they run forward and inward to reach the bladder 3.5 to 4.5 cm. ($1\frac{2}{5}$ to $1\frac{4}{5}$ in.) apart and the same distance behind the prostate. **In the female** they lie in the base or root of the broad ligament 12.5 to 18.5 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) external to the cervix uteri. Here they are *crossed in front by the uterine arteries* and pass through the uterine plexus of veins (Figs. 149 and 150). They then cross obliquely the upper third of the vagina, inclining forward from the lateral vaginal wall to the vesicovaginal interspace, and *enter the bladder* wall 6 mm. below the anterior fornix of the vagina. Hence, in the female, *a stone* impacted in the lower 6 to 7.5 cm. ($2\frac{1}{2}$ to 3 in.) of the ureter may be *palpated* through the vagina and an extensive carcinoma of the cervix or upper end of the vagina may involve and obstruct the ureters. In the male their lower extremities, if containing a calculus or thickened by disease, can be palpated through the rectum with some difficulty. Their *course and relations* in the female pelvis are of vital *importance in opera-*

PLATE XXXVI

FIG. 134



Pelvic Portion of the Ureters, Formation of the Spermatic Cord, Rectovesical Pouch, Pelvic Vessels, etc. (Testut.)

Male, seen from in front and above, the bladder being pulled forward.

tions on the female pelvic organs, and many cases are recorded where the ureter has been *injured in operations* on these organs. In such operations the distance between the ureters and the cervix is considerably increased if the uterus is pulled upward and forward. As a result of these injuries several methods have been successfully employed of uniting the divided ends of the ureters or re-implanting them into the bladder or colon when divided low down. They have also been attached to the surface for permanent drainage in a few cases.

The **relations** of the ureters are of importance for the purpose of finding or avoiding them as occasion requires. They cross obliquely the psoas muscles and the genitocrural nerves, being connected loosely with the muscle but firmly with the external surface of the peritoneum. From the latter circumstance they can be *readily found,* for, if the peritoneum is stripped up from the psoas, the ureters remain attached to the peritoneum 1.2 to 2.5 cm. ($\frac{1}{2}$ to 1 in.) from the attachment of the latter to the vertebræ on the left side and a little more on the right side, where the ureter is displaced outward by the vena cava. Psoas abscess has been known to discharge through the ureter. On section between the second and third lumbar vertebræ the right ureter is 4 cm. from the parietal peritoneum external to the outer border of the kidney; the left is 6 cm. distant.

In their course *in the abdomen* the ureters are *crossed anteriorly* by the spermatic (or ovarian) and colic vessels. The vena cava is almost in contact with the right ureter on its mesial aspect, while the left is separated from the aorta by 2.5 cm. (1 in.) above and 1.2 cm. ($\frac{1}{2}$ in.) below, opposite the aortic bifurcation. On the right side the ureter is in near relation to the appendix, and when the latter points inward and is adherent posteriorly the two may be in contact, though the lower end of the ileum often intervenes. The possibility of injuring the ureter should be remembered in operations on the appendix. *Near the pelvic brim* it crosses the common iliac artery close to its bifurcation, or the beginning of the external iliac (more often on the right side), and lies behind the sigmoid loop on the left side and the lower end of the ileum on the right. These relations are important in ligation of the iliac arteries.

In the pelvis the left ureter is lateral to the sigmoid mesocolon. *At the bladder* the ureter lies below the obliterated hypogastric artery, and in the male is crossed superiorly and internally by the vas deferens, which thus comes to lie between it and the bladder. The free end of the seminal vesicle overlaps it from below. The inner openings in the bladder are about 2.5 cm. (1 in.) from one another and from the vesical outlet.

Varieties and Malformations.—There may be only a *single ureter* from a fused kidney, or *two or even three ureters* may arise from one kidney, from the late union, or non-union, of the middle pelves which form the common pelvis. *Two malformations* may exist as the *cause of hydronephrosis:* (1) a kind of congenital valve at the commencement of the ureter; and (2) an origin of the ureter above the lower end of the pelvis, so that when the latter fills, it may press upon, narrow, or close

the valve-like opening of the ureter. In the latter cases the ureter appears to come from the upper or middle instead of the lower of the two or three middle pelves that make up the common pelvis.

The flow of urine through the ureters is due to the *peristaltic contraction* of their muscular coats, and occurs at *regular intervals.* It may be aided by gravity in the erect position.

Tourneur's point is at the intersection of a line connecting the tips of the twelfth ribs and of one drawn vertically from the junction of the inner and middle thirds of Poupart's ligament. It represents the commencement of the ureter, the level of origin of the spermatic or ovarian artery, and the lower extremity of the kidney. The course of the abdominal portion of the ureter is represented by a line from this point to the junction of the upper and middle thirds of the line for the iliac arteries (Morris). In this line we may palpate for tenderness in suspected lesions of the ureter. The **abdominal portion** of the ureters (*i. e.*, above the pelvic brim) may be **exposed** by an *incision* used to expose the kidney, passing obliquely from near the costovertebral angle toward the anterior superior iliac spine and then curving toward the umbilicus or running a little above Poupart's ligament; or, by an *incision* like that for the common iliac artery, carried farther upward. The *walls* of the ureter are about one twenty-fifth of an inch *thick*, composed mainly of muscular and fibrous tissue.

The *passage of a renal calculus* through the ureter is accomplished in much the same way as that of biliary calculi (p. 372) and with a similar intense, intermittent pain, known as *renal colic.* They are most likely to be arrested just above the constrictions of the ureter. The ureters have been *ruptured* by external violence. The resulting *extravasation* of urine is large, retroperitoneal, and liable to suppuration, producing a lumbar, iliac, or pelvic abscess.

The Suprarenal Bodies or Adrenals (Figs. 114, 121).—These are two *ductless glands*, one of which *rests on* the upper end and the adjoining parts of the anterior surface and inner border of each kidney. They are *separated from the kidney* by the perinephritic tunica adiposa, so that changes in position of the kidney do not affect the suprarenals. They are larger at birth than in the adult, they atrophy in advanced life, and are degenerated in connection with Addison's disease. They *rest upon the diaphragm* opposite the eleventh and twelfth ribs, and perhaps the tenth interspace, or opposite the adjoining portions of the eleventh and twelfth thoracic vertebræ. An interval of 5 to 6.2 cm. (2 to $2\frac{1}{2}$ in.) separates them from one another.

The **left** is *crescentic*, flattened from before backward, and extends lower down than the right one along the inner border of its kidney, even to the hilum. *In front* lies the stomach, separated by the lesser peritoneal sac, and its lower cornu is crossed by the pancreas and the splenic vessels. *Externally* it is in contact with the upper end of the spleen. The **right** suprarenal is more *triangular*, laterally compressed and vertically elongated, but reaches no higher than the left, owing to the lower position of the right kidney. It is *related in front* to both the inferior and posterior

surfaces of the right lobe of the liver (impressio suprarenalis); *internally* to the vena cava, which slightly overlaps it, and its *inferior angle* is crossed by the first bend of the duodenum. It lies behind the foramen of Winslow. The left suprarenal is covered with peritoneum above, the right below. In a three months' fetus the adrenal is much larger than and nearly surrounds the kidney, affording abundant opportunity for the occurrence of persistent misplaced portions in the renal cortex beneath the capsule. Such adrenal rests may be the starting point of both benign and malignant tumors belonging to the class of kidney tumors known as hypernephroma.

The *nerve supply* of the suprarenals is remarkably abundant, derived mainly from the solar and renal plexuses, with some branches from the phrenic and vagus nerves. Several cysts and tumors of the adrenals have been operated on. The suprarenals are generally disregarded in operations on the kidneys, except that the blood supply of the two is more or less connected, especially on the left side. The extract of these bodies is a remarkably strong astringent and vasomotor stimulant, and as such is much used therapeutically. It has also been used in Addison's disease, etc.

Bloodvessels of the Abdomen.—The following is in addition to the mention made under the several organs and the parietes:

The abdominal aorta varies in its distance from the ventral surface in different individuals, but in general it *approaches nearer the surface* as it nears its bifurcation. Hence the *most favorable point for compression* of the aorta is just above the umbilicus, for it bifurcates just below and to the left of this point. But even here it cannot be readily felt or satisfactorily compressed unless the bowels are quite empty.

Aneurysm is most likely to occur at or near the celiac axis, which is a weak spot, often giving way in injections of the cadaver, for here several large branches are given off, causing a sudden deviation in the course of the circulation and a sudden contraction in the size of the aorta. Such an aneurysm gives rise to a *pulsating tumor* in the epigastric or umbilical region, but a tumor of the organs in front of the aorta (pylorus, pancreas, colon) may also receive a pulsation (not expansile) from the aorta. *Pressure of the aneurysm* on the diaphragm, esophagus, and stomach may cause dyspnea, dysphagia, and vomiting; on the vena cava, edema of the legs; on the renal veins, albuminuria; on the lumbar nerves, pain in the back, buttocks, or thigh; on the sympathetic plexuses, indigestion, visceral pains, reflex pains in the lumbar nerves, etc.

Many of the *branches* of the abdominal aorta are of *large size*, the celiac axis and superior mesenteric are of the size of the common carotid; the hepatic, splenic, and renals equal the brachial in size. Aneurysm sometimes occurs on many of these branches.

The number of minute **extraperitoneal anastomoses** between the branches of the parietal vessels (lower intercostal, phrenic, lumbar, iliolumbar, epigastric, and circumflex iliac) and branches of vessels which supply viscera not entirely covered by peritoneum (liver, kidney, adrenals, duodenum, pancreas, ascending and descending colon) are of

great *importance in case of obstruction* to the arterial supply of the viscera. The corresponding *venous anastomoses* are of equal or greater importance in case of obstruction of either the vena cava or the portal vein. The *parumbilical vein* also directly connects the portal vein with the epigastric, and thus, with the external iliac veins, may be of much service in relieving obstruction of the portal circulation, as in cirrhosis (see also pp. 279 and 365). The above anastomoses explain the effect of surface bloodletting and counterirritation in inflammation or congestion of the partly extraperitoneal viscera.

The *celiac axis,* with a semilunar ganglion on either side, arises opposite the top of the first lumbar vertebra, about 10 cm. (4 in.) above the umbilicus. The *renal artery* arises opposite the lower end of the same vertebra (that of the right side somewhat lower), the *inferior mesenteric* about 5 cm. (2 in.) above the aortic bifurcation, or 3.7 cm. ($1\frac{1}{2}$ in.) above the umbilicus. The *left renal vein,* crossing in front of the aorta, to reach the vena cava, is an exception to the *rule* that below the diaphragm the large veins pass behind the large arteries, while above the diaphragm they pass in front.

Lymph Nodes of the Abdomen.—Besides the lymphatic nodes already noticed, in connection with the organs, there is a central series of *retroperitoneal lymph nodes* arranged around the aorta. The nodes on the sides of the aorta (juxta-aortic), those on the right side lying behind and in front of the vena cava, receive the lymphatics from the iliac nodes, the kidneys, genital organs, and parietes. Those in front of the aorta (pre-aortic) receive the lymphatics from the alimentary canal and its accessories. The upper nodes of this chain grouped about the origin of the superior mesenteric artery and celiac axis are sometimes called the celiac nodes, as distinguished from the lumbar or lower nodes. Great *enlargement* of these nodes may cause edema from pressure on the vena cava.

Nerve Supply of the Abdominal Viscera.—This is *derived from* a series of connected *plexuses* in front of the abdominal aorta, formed by the *sympathetic system* with some branches from the vagus and phrenic nerves. The two *great splanchnic nerves,* descending from the thorax, end in the two large **semilunar ganglia,** one on either side of the celiac axis. These are united together, and with many small surrounding ganglia, by a network of fibrils to form the **solar plexus,** behind the stomach, above the pancreas, between the adrenals, and in front of the aorta and crura of the diaphragm. It also receives twigs from the vagus and phrenic nerves. From this central plexus *branch plexuses* are derived which accompany the visceral branches of the aorta, except the inferior mesenteric, to the organs which they supply. The *renal plexus* also receives the least splanchnic nerves. Mesial branches of the lateral sympathetic cords form the **aortic plexus** in front of the aorta between the superior and inferior mesenteric arteries. Along the latter a branch of this plexus, the *inferior mesenteric plexus,* passes to the viscera supplied by the artery.

These plexuses, and the nerves which go to form them, communicate with the thoracic and lumbar spinal nerves, and thus account for many

reflexes, i. e., the reflex pains and muscular contractions in the course of the spinal nerves in cases of peritonitis, etc. (see p. 281). The "sympathetic" or *reflex pain between the shoulders*, or about the angles of the scapulæ, in some diseases of the stomach and liver, are probably due to a reflex in the fourth, fifth, and sixth thoracic nerves, which supply these parts and communicate with the great splanchnic nerves which, through the solar plexus, go to supply the liver and stomach. Owing to the centralization in the great nerve plexuses in the abdomen, almost all acute troubles in the abdomen begin with the same group of symptoms (Treves). Reflex pain in the tip of the shoulder has already been referred to. (See Liver, p. 366.)

From the extent of these abdominal nerve centres, especially the solar plexus, we can understand what *profound effects*, collapse, vomiting, and even death, may *attend an injury* to them or the viscera most closely associated with them. Hence the danger of a blow over the pit of the stomach, *i. e.*, over the solar plexus, which may even cause death from cardiac inhibition without marks of external injury, and always causes shock out of all proportion to the extent of the injury. Hence, also, an injury to those viscera which are more remotely connected with the nerve centres, such as the descending colon, which is supplied by the inferior mesenteric plexus, only indirectly connected with the solar plexus, or even the ascending colon, supplied by a part of the superior mesenteric plexus most remote from the centres, is accompanied by less serious symptoms. It is noteworthy that the nearer the lesion is to the stomach, other things being equal, the more profound are the nervous phenomena produced. *Distant pain* in disease of the abdominal viscera is not necessarily reflex, but *may be due to pressure*. Thus pain in the knee may be due to the pressure of the sigmoid flexure, distended with feces or affected with cancer, upon the obturator nerve.

CHAPTER V.

PELVIS AND PERINEUM

THE PELVIS.

We have already studied, in a preceding section, the upper part or false pelvis which supports some organs and attaches many muscles of the abdomen. It remains to study the true pelvis and its viscera. The **external or superficial boundaries** of this region are not well-marked, for it is covered by the parts of other regions, *i. e.*, the buttocks behind, the hips at the side, and the perineum below. Hence there are but **few bony or other landmarks.** Some of these we have considered under the landmarks of the abdomen (see p. 268).

From the pubic spine to the symphysis we can make out the *front of the pelvic brim,* formed by the pubic crests, and below this the bodies of the two pubic bones, separated by the symphysis pubis. This part is covered in the female by a thick pad of subcutaneous fat, the **mons veneris,** which somewhat obscures the bony outlines. The mons veneris is separated from the abdomen above by a transverse furrow which meets the inguinal furrows about their centre.

Still farther down in the median line we can feel the **subpubic angle** on deep pressure behind the scrotum in the male, in the vestibule in the female. Leading from this angle to the ischial tuberosities we can trace the combined **ramus of the pubis and ischium** on each side, which bound the perineum laterally and lie nearly in the **genitocrural furrows.** The latter are the furrows between the inner aspect of the thighs and the perineum, and are continuous behind with the *gluteal folds.* It is near the inner end of the latter that the **ischial tuberosities** can be readily felt. In the sitting posture these tuberosities are only separated from the skin by the subcutaneous fat and a **bursa.** This bursa is *liable to inflammation* in those who sit a great deal, like coachmen, weavers, etc. In the standing posture the tuberosities are overlapped by the lower borders of the gluteus maximus muscles. The ischial tuberosities form one end of *Nélaton's line* (see p. 486) and the line connecting them with the central point of the perineum divides the perineum proper in front from the ischiorectal fossa behind.

In the *median line behind* we can feel the *spinous process* of the fifth lumbar vertebra, often indicated by a little furrow, and below this those of the sacral vertebræ, of which the third is the most prominent. Following down in the median line, in the deep fold between the buttocks, we can feel the **tip of the coccyx,** behind which (especially in women) there is often a more or less marked dimple or depression of the skin

(*foveola*). *Through the vagina or rectum* can be *felt* posteriorly the front of the coccyx and sacrum, laterally the spines, the inner aspect of the tuberosities and the bodies of the ischia and the great sacrosciatic foramina, and anteriorly the back of the pubic bones and symphysis and the obturator foramina. With a long finger or half hand, when the patient is anesthetized, the **sacral promontory** can be felt above and behind, but if this can be felt in an ordinary examination by a finger of ordinary length the pelvis is considered abnormal. The promontory can also be felt on deep pressure through a thin lax abdomen, about on a level with the anterior superior iliac spines.

The Bony Pelvis.—Although in the bony state the inlet or *brim* of the pelvis is *heart-shaped*, with the base behind, in the natural state the psoas and other muscles make it *triangular*, with the base in front. The *outlet* of the pelvis is composed of *three bony points* separated by *three notches*. The two symmetrically placed posterior notches (sacrosciatic) are bridged across by the strong *sacrosciatic ligaments*, which thus bound the pelvic outlet and make it lozenge-shaped. The *tuberosities of the ischium* may be quite close together in the male. I have seen this condition so marked as to embarrass one in lateral lithotomy. In the natural position of the pelvis the tuberosity lies behind and below the acetabulum, and only a trifle farther behind it than the anterior superior iliac spine is in front of it. The level of the *ischial spine* lies 1.5 cm. ($\frac{3}{5}$ in.) above the upper border of the symphysis.

The **coccyx** may be *fractured or dislocated* as a result of falls or blows or during parturition, especially in those women in whom the coccyx is much incurved as the result of sedentary habits or horseback riding. The displacement of the fracture or dislocation may be readily made out by rectal examination, or by a finger in the rectum and the thumb on the surface. The *joint* between the coccyx and the sacrum may also be sprained or *diseased*. All these conditions are very painful, owing to the frequent movement at the seat of injury or disease, due to the muscles attached to the coccyx (gluteus maximus, coccygeus, levator, and sphincter ani). The injured bone may project into the rectum and be moved in defecation mechanically as well as by the sphincter and levator ani muscles. The sacrococcygeal joint and the parts about the bone are supplied by the posterior divisions of the coccygeal and the second to the fifth sacral nerves and the anterior divisions of the fifth sacral and the coccygeal nerves, which may be the seat of a painful neuralgia (*coccydynia*). *Removal* of the coccyx may be called for on account of injury, joint disease, or neuralgia.

Sacrococcygeal Tumors and Cysts.—These are *congenital* in origin, and I have seen them attain such a size that the possessor, a man, wore skirts to conceal the enormous mass. They grow on the posterior or the anterior surfaces (between the bone and the rectum). They belong to the class of tumors known as teratoma, which includes tumors ranging from the simple coccygeal lipomata and dermoid cysts to the more complicated thyroid dermoids, etc., which contain tissues derived from all three germ layers. They are supposed to *arise from* the embryonic

neurenteric passage, or postanal gut, many claim the more complex tumors are bigerminal in origin and derived from a parasitic twin. The *dermoids* over the back of the sacrum and coccyx may be confounded with spina bifida. *Attached human fetuses* are often joined together at this part of the column, and here, too, third limbs (tripodesia) and parasitic fetuses are found attached.

Sacro-iliac Joint.—Normally there is no movement in this joint except, as Farabeuf has shown, a *slight rotation* on a transverse axis. Thus when the thighs are flexed onto the abdomen, the conjugate diameter is shortened by the rotation upward of the innominate bones, the symphysis approaching the promontory. The sacrosciatic ligaments resist this rotation. The reverse movement occurs on hyperextension of the thighs. The difference between these extremes is about 1 cm., so that extension may be made use of in obstetrics to slightly increase the conjugate diameter of the brim. In general the *joint serves* merely *to break shocks,* but some movement is said to occur when the ligaments are softened by disease.

The *joint* may become **diseased** as the result of injury, by an extension from spinal caries, etc., or spontaneously. In the latter two instances it is usually tuberculous. In disease of this joint much *pain* is felt *in standing or sitting,* as in these positions the weight of the body is transmitted through it, and pain is also felt in any movement that involves the action of muscles attached to the ilium. This pain, besides being local, may also be of a *peripheral reflex character* over the sacral region (upper sacral nerves), in the buttocks (superior gluteal nerve), or even at times in the thigh and calf (lumbosacral cord). The above-named *nerves supply the joint,* which sometimes gets a small twig from the obturator nerve which, with the lumbosacral cord, passes over the front of the joint. The obturator nerve accounts for referred pain in the knee- or hip-joints. The body is inclined to the sound side to diminish the pressure on the diseased joint. Tenderness may be elicited by pressing together or separating the ilia or by direct pressure about the posterior superior iliac spine, which corresponds to the centre of the joint.

If **abscess** forms it usually *comes forward* into the pelvis, as the anterior ligaments are much the thinner and weaker. Such an abscess may enter the iliopsoas sheath, perforate the rectum, enter the ischiorectal fossa, or follow the lumbosacral cord and sciatic nerve to the back of the thigh, or the obturator nerve to the inner aspect of the thigh. More rarely the abscess may pass backward and point behind the joint.

In spite of the comparative weakness of the anterior sacro-iliac ligaments, above mentioned, *dislocation* never occurs except in fracture of the pelvis, or the rare luxation of the sacrum anteriorly. This fact is due to the very strong posterior sacro-iliac ligaments, which sling the sacrum from the ilium, and not to the wedge shape of the sacrum, for, in the natural position of the pelvis, the base of the wedge looks downward and forward, *i. e.,* in the direction in which the weight of the body would naturally tend to displace it. The wedge shape would prevent its being dislocated backward, but there is no tendency to displacement

in this direction. At the same time, owing to the irregularities of the bony surfaces and the slightly projecting lips of the ilia in front and below, the sacrum is more or less wedged in between the ilia like the keystone of an arch, to the pillars of which, the ilia, it transmits the weight.

The symphysis pubis is nearly 5 cm. (2 in.) in *height*, and its *thickness* may reach nearly 2.5 cm. (1 in.). In **symphysiotomy**, proposed by Sigault in 1768 as a substitute for Cesarean section to enlarge the pelvic dimensions in labor in cases of contracted pelvis, a separation at the symphysis of 6.2 cm. ($2\frac{1}{2}$ in.) increases the conjugate diameter by only 12 mm. ($\frac{1}{2}$ in.). But, as the convexity of the child's head may project into the interval between the separated pubic bones, another 12 mm. or so may be gained for the passage of the head. The *innominate bones* can be *separated* at the symphysis, but a very little distance without first straining the front of the sacro-iliac joint, then tearing the anterior ligaments and the cartilages connecting the bony surfaces. A separation of 7 cm. at the symphysis is possible without laceration of these ligaments. In addition to the tearing of the anterior ligaments, the *periosteum* is usually *stripped up* for some distance on the ilium in front of the joint. As the axis of this separation or opening of the joint is at the back of the joint and passes obliquely downward and inward, the strong posterior sacro-iliac ligaments avoid injury and the pubic bones on being separated pass downward as well as outward. In addition to the laceration of the sacro-iliac joints, the attachments of the pelvic viscera may be damaged. A slight separation of the pubic bones due to swelling of the fibrocartilage has been shown to occur toward the end of gestation, but during parturition the decussating tendinous fibers of the abdominal muscles, which cross in front of the joint, would tend to brace the bones more tightly together.

Separation at the symphysis without fracture of the bones is very rare, but has occurred from severe external violence, and Malgaigne has reported three cases where the violence was merely muscular, due to excessive action of the adductors of both sides.

The Mechanism of the Pelvis.—The *weight of the body is transmitted* from the sacrum through the pelvis *along two arches:* one for the standing, the other for the sitting posture. The *arch for the standing posture* consists of the sacrum, the sacro-iliac joints, the acetabula, and the thick ridges of bone along the iliopectineal line between the two latter points. For the *sitting posture the arch* is much the same, except that the ischial tuberosities are substituted for the acetabula. These *two arches* have been called the *femorosacral* and the *ischiosacral* respectively. The bone in the line of these two arches is much thicker than elsewhere in the pelvis. The sacrum occupies the position of the keystone for both arches (see above, p. 396).

To strengthen each arch its ends are joined by a *counterarch*, which completes a ring and serves as a tie to keep the sides of the arch from either separating or collapsing. The counterarch or tie of the femorosacral arch is formed by the bodies and horizontal rami of the pubes, that of the ischiosacral arch by the combined rami of the pubes and ischia.

Thus the *ties* of both arches *meet at the symphysis,* to which is conveyed a portion of the weight or strain. Hence the strain felt at the symphysis when increased weight is to be borne, as in pregnancy, abdominal tumors, etc., and hence the powerlessness in standing or sitting when the symphysis is diseased or weakened by injury or an unhealed symphysiotomy.

Pelvic Deformities.—Pelvic deformities are also explained, according to the mechanism of the pelvis, by the pull of muscles and the weight of the trunk acting on bones that have not become properly ossified in parts, owing to *rickets,* or on bones more uniformly softened by the much rarer condition, osteomalacia. When the rickety child walks but little and sits most of the time, as they frequently do, the weight of the body thrusts the sacral promontory forward and downward, thus diminishing the conjugate diameter of the brim. The *counterpressure* comes from the ischial tuberosities and is most felt in the counterarch, which is narrowed and pushed forward at the symphysis, while the tuberosities may approach one another and narrow the transverse diameter of the outlet, or may diverge, widening the transverse diameter and the subpubic angle. If the rickety child is more on its feet, lateral counterpressure is exercised at the acetabula, and is felt mostly at the weakest part of the pelvis, *i. e.,* the counterarch. Thus while the acetabula approach one another more or less, the most marked change is often a beak-like projection of the symphysis, the pubic rami sometimes running parallel with one another and close together, showing a collapse of the counterarch. There are many and diverse pelvic deformities depending upon modifications of the pressure and counterpressure and the pull of the muscles.

In the softer condition due to *osteomalacia,* which occurs only in adult life, the changes due to lateral pressure are most marked.

Fractures of the Pelvis.—Though the sacro-iliac joints and the symphysis might be thought to be weak points of the pelvis, their connecting ligaments are so strong that they rarely give way primarily; the bones yield first. As has just been said, the *counterarch* is the *weakest point,* and it is *here that fracture commonly occurs* from the most varied forms of violence. Fractures of the pelvic arch usually occur as the result of violent pressure on the surface or of falls from a height. Thus if the force be applied in the anteroposterior direction, the weak counterarch yields to direct or indirect violence on one or possibly both sides of the symphysis through the pubes or the rami. The force continuing tends to separate the two innominate bones and to cause a diastasis and finally a dislocation of the sacro-iliac joints, as in symphysiotomy, or a fracture of the ilium external to these joints. Again, if the force be applied transversely, the pelvis tends to become flattened laterally, but the weaker counterarch is more flattened, and eventually gives way and is fractured by indirect violence. Should the force continue, the two hip bones are pressed toward each other and the strain on the sacro-iliac joint falls upon its posterior part. Here the ligaments are so strong that, instead of their rupture, portions of bone to which they are attached, especially the sacrum, are usually torn away. In falls on the feet or

ischial tuberosities it is again the weaker or counterarch which is usually fractured. In falls from a height or other severe injuries the head of the femur may be driven through the acetabulum, but this is rare.

A *separation* of the hip bone *into its three constituent parts* cannot occur after about the eighteenth year, at which time the three parts are firmly united by the ossification of the Y-shaped cartilage. Before this occurs *abscess* within the capsule of the hip joint may make its way into the pelvis through the cartilage, but this is not as common an occurrence as one would expect. Separation of the epiphysis of the iliac crest and spines may result from direct violence or even from muscular action. Localized direct violence of sufficient force may fracture any part of the pelvis.

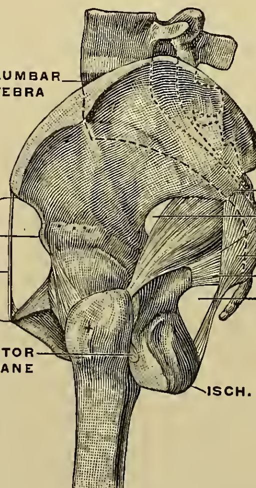
Apart from the fact that the violence producing fractures of the pelvis is usually severe and entails shock and often other remote injuries, such fractures are serious on account of and in proportion to the *injury to the pelvic viscera* from sharp fragments or loose pieces of bone, or from crushing or tearing. Thus the bladder and urethra, and in the female the vagina, are especially liable to be torn by sharp fragments, and the urethra may be ruptured or compressed, owing to its close relation to the subpubic arch. A vesical calculus has been reported having for its nucleus a piece of bone driven into the bladder in a fracture of the pelvis. It is in the *double fractures* of the pelvic arch that the viscera are most often wounded. In these double fractures the two lines of fracture are most often on one side of the symphysis, rarely on both; or in place of the second fracture we may have a diastasis of the symphysis, which usually occurs, if at all, in connection with fractures of the pelvic arch. Or if the second fracture passes through the ilium, a little external to the sacro-iliac joint, the large pelvic fragment may be displaced upward with the attached femur and lead to a mistaken diagnosis of fracture of the neck of the femur. But the relation of the great trochanter to the anterior iliac spine is unaltered. The rectum, too, has been torn or compressed in fractures of the sacrum or coccyx. Information may often be gained for the *diagnosis* of fracture of the pelvis by rectal or vaginal examination, and blood in the urine in such cases indicates an injury to the bladder or urethra. The capsule of the hip joint is almost always external to the line of fracture of the pelvic arch, and thus escapes injury.

In the erect position the *plane of the brim* or inlet of a normal pelvis makes an angle of about 60 degrees with the horizon, which is due to the sacrovertebral angle and the obliquity of the articulation of the hip bones with the sacrum. This anteroposterior tilting, which we call the *obliquity of the pelvis*, varies in different cases, and averages greater in the female than in the male. In hip disease, with ankylosis of the hip-joint in the flexed position, the pelvis, as a whole, moves about the transverse axis, passing through the acetabula, and its obliquity is increased on standing, in order to bring the ankylosed limb into a vertical position. To allow of this increased obliquity of the pelvis the forward convexity of the lumbar vertebræ is increased (*lordosis*) by their extension.

Increased obliquity causes a protrusion of the belly and a backward position of the external genitals. The normal obliquity of the pelvis may be shown by placing the anterior superior iliac spines and the pubic spines in the same vertical plane, as against the wall (H. v. Meyer).

The *inclination of the pelvic outlet,* or the angle between the horizon and the line connecting the tip of the coccyx with the lower border of the symphysis, averages from 12 to 15 degrees. The *axis of the inlet,* or the line at right angles to the centre of its plane, passes obliquely forward and upward, so that if prolonged it would meet the umbilicus above and the middle of the coccyx below. The *axis of the outlet* prolonged upward touches the base of the sacrum, and prolonged downward is directed slightly backward, whereas the curved line representing the axis of the entire pelvis, if prolonged downward, would curve forward. This

Fig. 135



Female pelvis viewed from the left side, showing the position of its parts in the erect posture. (Joessel.)

distinction is not always understood. The *axis of the cavity,* nearly straight above, more curved below, is parallel to the curve of the sacrum and equidistant from all sides of the pelvis. The descent of the fetal head follows this curved line, turning as it were around the symphysis as an axis. As this curved axis, continued downward, passes near the centre of the vulva, those cases where the vulva is unusually far forward are more exposed to rupture of the perineum in delivery. It is also in this curved direction that instruments (sounds, forceps, etc.) are passed to the pelvic viscera.

With a normal inclination of the pelvis, the sacral promontory lies 9.5 cm. ($3\frac{4}{5}$ in.) above the upper border of the symphysis and the tip of the coccyx 1.2 to 2.5 cm. ($\frac{1}{2}$ to 1 in.) above its lower border. The long axis of the symphysis forms an angle of 100 degrees with the conjugate diameter of the brim, *i. e.,* the line between the promontory or sacro-

vertebral angle and the upper end of the symphysis. This fact is of importance in obstetrics, as the fetal head makes one of its principal turns around the symphysis.

Obstetricians consider *three diameters:* ventrodorsal or conjugate, transverse and oblique, *in three planes* of the pelvis, that of the brim, the centre or largest part of the cavity, and the outlet. The oblique diameter is between the sacro-iliac joint and the inner surface corresponding to the acetabulum of the opposite side, measured at the inlet, the outlet, and in the cavity. The transverse diameter at the outlet is the distance between the ischial tuberosities. The measurements of the diameters vary according to age, sex, and individuality, and especially in the presence of pelvic deformities. In the female they average as follows:

	Anteroposterior.		Transverse.		Oblique.	
	Cm.	Inches.	Cm.	Inches.	Cm.	Inches.
Inlet	11.0	4⅜	13.25	5¼	12.5	5
Cavity	12.7	5	12.5	4⅞	13.0	5¼
Outlet	11.5	4½	11.0	4⅜	11.5	4½

If the measurements are materially diminished symmetrically, as in cases of "equally contracted pelvis," in women apparently well formed, or unsymmetrically in rachitic pelvic deformities, normal labor may be rendered difficult or impossible. It should be noted that the pelvis does not form a complete unyielding bony ring in any horizontal plane, but that everywhere a firm bony portion has opposite to it soft and yielding parts.

The apparently greater width of the *female pelvis,* as shown by the hips, is due to the greater amount of subcutaneous fat and the comparison with the narrower waist. The distance between the anterior superior spines averages 6 to 10 mm. ($\frac{1}{4}$ in.) greater in the female, that between the iliac crests averages 1 cm. ($\frac{3}{8}$ in.) greater in the male, while Quain gives both greater in the male. The true pelvis is shallower, broader, and more capacious in the female; the false pelvis is relatively narrower and less deep in the female (Quain). In the female, too, the symphysis is less deep and both the subpubic arch and the distance between the ischial tuberosities is much wider, all of which are of importance in the mechanism of labor.

The pelvis, as a whole, may *move on three axes:* a transverse (flexion and extension), an anteroposterior (tilting), or a vertical (rotation). *These movements take place in the lumbar spine.* Flexion and extension are the most important and the most extensive, and decrease or increase the obliquity of the pelvis, respectively. When the hip joint is fixed or ankylosed it is the pelvis that is flexed or extended on the transverse axis passing through the acetabula. It is enabled to do this by movements of the lumbar spine in the same direction (see above, p. 399).

Normally the pelvis is on the same level on the two sides, so that the line joining the two anterior superior iliac spines is horizontal in the erect position. Pathologically this line may be oblique, so that there is

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a lateral obliquity or *tilting of the pelvis* on an anteroposterior axis. In such a case one side of the pelvis is raised, while there is a *lateral curve of the lumbar vertebræ* toward the opposite side to enable the trunk to be held erect. This is often the *result of* hip disease, where the thigh on the affected side may be fixed in the ad- or abducted position, and the pelvis is tilted to allow the limbs to hang vertically in standing or walking. Or it may result from a shortened limb, from fracture or any other cause, and the length of the two limbs is made apparently and often, for practical purposes, virtually equal by the tilting of the pelvis downward on the side of the shortened limb.

These facts have an important bearing on the *measurements of the length of the lower extremities.*

Before illustrating the bearing of these facts on such measurements, it is well to notice that the *anterior superior iliac spines,* from which we take our *measurements,* lie lateral to the acetabula. Hence *we measure* the long side of an oblique-angled triangle of which the short side is the line between the iliac spine and the acetabulum, and the third side is the lower limb itself. If the *two limbs* are *of equal length* and one is fixed at the hip in the abducted position, the other limb, to be parallel with it, must be adducted (Fig. 136, ACM′ and A′CM″). By a lateral tilting of the pelvis both limbs are made apparently straight and in the long axis of the body (Fig. 137). The pelvis on the abducted side is lowered by the tilting, hence its acetabulum is lower than that of the opposite side. Therefore the limb on the abducted side will appear longer (*apparent lengthening*) than that on the adducted side, which cannot touch the ground. If, however, we measure the two sides, we are surprised to find that the abducted and apparently longer limb measures less (*measured shortening*) than the other, while in reality the two are exactly equal in length.

The *explanation* is simple. As one limb is gradually abducted, the triangle, whose long side we measure, approaches more nearly a right-angled triangle until it becomes one, hence the length of the long side we measure decreases as we abduct, for, the two sides remaining the same, the long side decreases in length as the angle decreases from an oblique angle to a right angle, and vice versa. As the other limb is gradually adducted the obtuse angle in the triangle increases, so that the long side measures more and more until the side representing the limb is in line with the short side of the triangle, and then the line we measure coincides with two sides of the triangle, which, according to a rule of geometry, are always greater than the third side (Fig. 137, A′CM′).

Hence we see that *abduction decreases measured lengthening* and *adduction increases it.* Therefore, in measurements to determine the comparative length of the limbs it is necessary to see that there is neither abduction nor adduction. This we do by seeing that there is no tilting of the pelvis and that the limbs are in the long axis of the body, or, in practice, that the line connecting the anterior superior iliac spines (Fig. 136, AA^1) is at right angles to the long axis of the body (Fig. 136, VP), and that the latter prolonged is equidistant from the malleoli of the two feet to

which we measure (Fig. 136, MP–PM). Or stretch a string or bandage from the umbilicus to the midpoint between the two ankles (Fig. 136, VP) and see that this is at right angles to a line connecting the two anterior superior iliac spines (Fig. 137, AA′).

Another anomaly is that if one side is actually a little shorter (*actual shortening*) and the pelvis is tilted, the short limb, if adducted, may appear shorter and measure longer than the longer limb, or, if abducted, it may appear longer and measure shorter. When the pelvis is tilted and the limbs are in the long axis of the body the limb on the lower side is always

Fig. 136

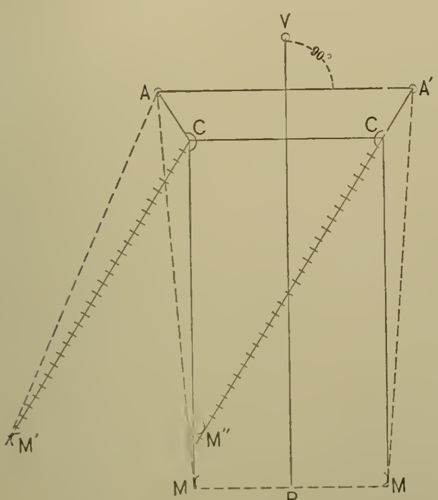
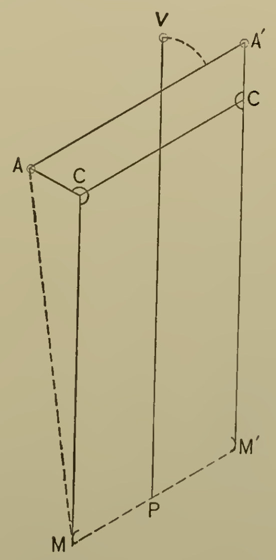


Fig. 137



Diagrams to show the correct (Fig. 136) and the incorrect (Fig. 137) position for measurement of the lower extremity and the effects of ab- and adduction on the apparent and measured length of the limbs. The plain lines in Fig. 136 show the correct position for measurement; the crossed lines represent the left-hand limb abducted, the right adducted. This same position is shown in Fig. 137, but the pelvis is tilted to bring the limbs in line with the axis of the body: *A*, anterior superior iliac spine; *C*, cotyloid cavity; *V*, umbilicus; *M*, malleolus; *P*, point equidistant from the two malleoli; *VP*, line from this point to the umbilicus; *AA*, line connecting the two iliac spines; *AM*, the line of measurement; *CM*, the real length of the limb; *AC*, the line from the iliac spine to the cotyloid cavity.

abducted, and vice versa. *Actual, measured, and apparent shortening* do not coincide unless there is no tilting of the pelvis. If one limb is a little shorter as a result of fracture of the femur, old hip trouble with loss of substance of the head, excision of hip joint or knee joint, etc., it may be *made of equal length* with the other, to all appearances and for all practical purposes, by tilting the pelvis down on the short side and up on the long side, and abducting it on the former and adducting it on the latter. The slightly shorter limb would appear equal, but measure considerably shorter. Thus fracture of the femur with 2.5 cm. (1 in.) or so of shorten-

ing may be compensated for by such a slight tilting of the pelvis that it is scarcely noticed and produces no awkwardness of gait. The pelvis may also be *rotated on a vertical axis* so that one anterior superior iliac spine is in advance of the other. This may also occur in hip disease.

The Lining of the Pelvis.—Pelvic Floor or Diaphragm.—At the *sides of the pelvis* the ischium, the obturator membrane, and the bony margins bounding it are well padded by the thick obturator internus muscle. At the *back of the pelvis* is the pyriformis on either side, while *the outlet* is occupied by the *coccygeus* behind and the *levator ani* in front. These latter two muscles, especially the levator ani, form the sagging *floor or diaphragm* of the pelvis and separate its cavity from the perineum in front and the ischiorectal fossæ behind. Indeed, the pelvis is so well padded that the bone appears in but two places, the pubis in front and the spine of the ischium laterally.

The anterior border of the **levator ani** passes backward and downward along the side of the prostate, and some of its fibers unite beneath it with those of the opposite side at the central tendinous point of the perineum, where they blend with the external sphincter ani and the transversus perinei muscles. The posterior fibers of the levator ani are attached to the tip of the coccyx. The rectum in both sexes and the vagina in the female perforate in the median line the pelvic floor, formed by the levator ani, and at these points the fibers of the muscle interlace with the longitudinal muscle fibers of the walls of those organs, more intimately with those of the rectum. Elsewhere in the median line the levator ani is attached to the median fibrous *raphê*, extending from the coccyx to the rectum and thence to the central tendinous point of the perineum.

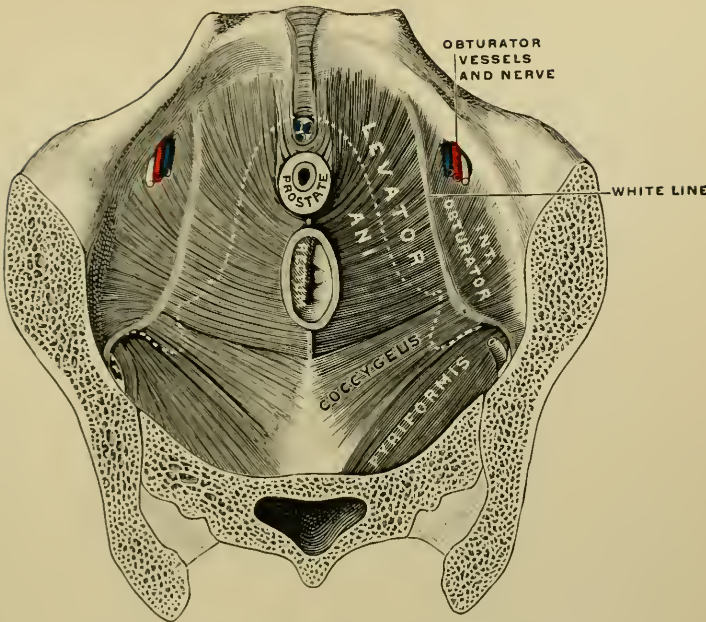
Besides the openings for the rectum and vagina there are several *small openings* in the pelvic walls *for the passage of vessels and nerves:* (1) through the *great sciatic notch,* above the pyriformis, for the superior gluteal vessels and nerves; (2) through the great sciatic notch between the pyriformis and the coccygeus for the internal pudic and sciatic vessels and nerves and the inferior gluteal vessels; (3) through the *obturator foramen* above the internal obturator muscle for the obturator vessels and nerves. The gap in the pelvic floor between the levator ani muscles in front is filled by the triangular ligament, which is pierced by the urethra and, above it, by the dorsal vein of the penis, or the corresponding vein in the female.

Pelvic Herniæ.—Through the first two foramina above mentioned, two of the forms of pelvic herniæ occur.

Obturator hernia occurs through the *obturator canal,* which is *directed* downward, forward, and inward beneath the horizontal ramus of the pubis for about 2 cm., with a *diameter* of 1 to $1\frac{1}{2}$ cm. Such a hernia pushes a sac of pelvic peritoneum before it and sometimes the obturator fascia. It comes to *lie deeply* beneath the pectineus and adductor longus muscles, by separating which it may be *exposed through an incision* near the inner border of Scarpa's triangle. It is often best to reach it by abdominal incision above the pubes. The *obturator vessels and nerves* are usually on the outer side, or, next most commonly, the nerve may be in front and

PLATE XXXVII

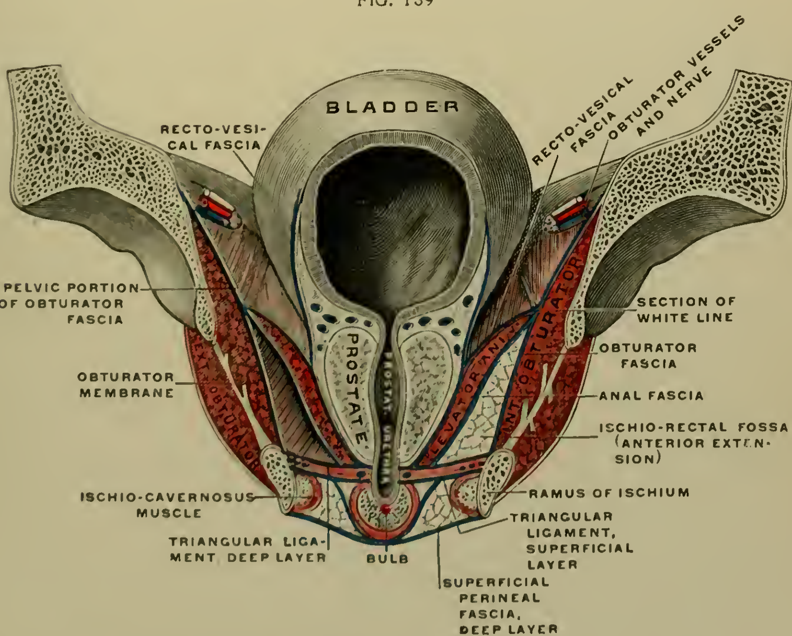
FIG. 138



Pelvic Floor in the Male. (Testut.)

The fascia is in place on left and is removed on right side. The dotted line outlines the bony outlet of the pelvis.

FIG. 139



Frontal Section of the Pelvis through the Middle of the Ischio-pubic Rami. (Testut.)

Partly diagrammatic, to show the pelvic fasciæ. Anterior segment of the section viewed from behind. The fasciæ are in blue.

the artery behind. The proximity of the nerve, which supplies the hip and knee joints and the adductor region, renders peripheral pain from pressure a conspicuous symptom, which has misled surgeons into treating it for some other condition. As the hernia lies on the mesial side of the hip capsule, pain on moving the hip is often a marked symptom. Obturator herniæ generally occur in advanced age and much more commonly in females, in whom, it is well to note, the inner orifice of the canal can be examined through the vagina. The hernia is too deeply situated to be evident in Scarpa's triangle, and may best be detected by palpation along the pubic ramus and behind the adductor longus, while the thigh is flexed, adducted and rotated out, or by vaginal or rectal examination. Strangulation is the rule.

Ischiatic hernia, escaping through the great sciatic foramen, above or below the pyriformis, lies beneath the gluteus maximus muscle. It is rare.

Other **rare forms of herniæ** occur through the pelvic floor, whose starting point we know only imperfectly. They occur in adults, usually in women, and to one side of the median line. The sac, covered by the rectovesical fascia, escapes through the fibers of the levator ani muscle or between it and the coccygeus, to appear in the posterior part of the labium majus (*pudendal hernia*), in the perineum (*perineal hernia*), in the ischiorectal fossa (*ischiorectal hernia*), or in the vagina (*vaginal hernia*). A rare form of hernia, whose sac is covered on one side by the rectal wall, may appear outside of or just within the sphincter ani muscle (*rectal hernia*). In perineal hernia the sac escapes in front of the rectum, between it and the vagina or prostate, and in pudendal hernia it escapes between the ischial ramus and the vagina.

Pelvic Fascia (Fig. 139).—The muscles of the walls and floor of the pelvis are lined by a fascia, the pelvic fascia. This helps to form a sheath for the muscles and to separate more effectually the pelvic cavity from the perineum and ischiorectal fossæ, and it serves to strengthen and support the pelvic viscera by its reflections onto them. Certain parts of these reflections onto the viscera are called their *true ligaments*, as in the case of the bladder, etc. Two principal portions are distinguished, a parietal and a visceral.

The parietal portion comprises the deep layer of the triangular ligament in front, the fascia covering the pyriformis behind, and the *obturator fascia* at the sides. The latter lines the obturator internus and is *continuous with* the iliac and transversalis fasciæ at the pelvic brim, along which it is attached. It is also *attached to* the free border of the ischium, the falciform process of the great sacrosciatic ligament, and the inner lip of the lower border of the ischiopubic ramus. At the latter attachment it is continuous on either side with the deep layer of the triangular ligament. The obturator fascia forms a fibrous canal for the internal pudic vessels and nerves. Along a line from the back of the pubis to the ischial spine the levator ani is attached to this fascia, which is here thickened and hence appears white (the *white line*). The obturator fascia above this line is sometimes distinguished as "*the pelvic fascia*."

From this white line is given off the visceral portion, or **rectovesical fascia,** which lines the upper or pelvic aspect of the levator ani and coccygeus muscles and is *reflected onto* the pelvic viscera where they penetrate this muscular floor, *i. e.*, rectum and vagina, and onto those immediately related to the pelvic floor, bladder, prostate, seminal vesicles, and uterus. According to some the fascial layer which goes to the viscera is reflected from the visceral layer of pelvic fascia along a tendinous arch, just internal to the white line, from the ischial spine to the puboprostatic ligament. From the lower end of the bladder it is reflected down to form the *fibrous capsule of the prostate,* at the apex of which it is continuous with the deep layer of the triangular ligament. It thus encloses the vesicoprostatic plexus of veins. From either side of the symphysis a fold of this fascia, covering a small bundle of muscle tissue prolonged from the bladder (vesicopubic muscle), passes back to the prostate and bladder as the anterior true ligaments of the bladder (*puboprostatic ligaments*). In the depression between the latter the pelvic fascia is thin, and through it is seen a plexus of veins, connected with the dorsal vein of the penis, which lies beneath the plexus. The fold from either side of the pelvis to the sides of the bladder, the lateral true ligaments of the bladder, are scarcely demonstrable. Farther back the fascia passes across between the bladder and the rectum, uniting yet separating them in the trigonal area and investing the seminal vesicles and the vasa deferentia. The lower end of the rectum also receives a thin prolongation of the fascia. The fascia where it is reflected onto the viscera is easy to trace, but becomes less and less distinct as it is followed from this point.

Behind the coccygeus the rectovesical and obturator fasciæ are continuous with the fascia covering the pelvic aspect of the pyriformis muscle. At the anterior border of the levator ani the rectovesical fascia above it joins the anal fascia beneath it and is continued forward to the obturator fascia, or its prolongation the deep layer of the triangular ligament. It is thus seen that the pelvic fasciæ form a continuous lining of the pelvic cavity.

The reflections and attachments of the rectovesical fascia *exclude certain viscera,* or parts of viscera, *from the pelvic cavity, i. e.*, the prostate, seminal vesicles, trigone and outlet of the bladder, and the lower 4 to 5 cm. ($1\frac{1}{2}$ to 2 in.) of the rectum. These may be wounded without entering the pelvic cavity, and, provided their fascial sheath is intact, suppuration in them would tend to spread toward the perineum and not into the pelvis. On the rectum the fascia reaches some little way below the rectovesical pouch of peritoneum in front.

The *pelvic vessels* are on the inside of the fascia, the *nerves* of the sciatic and lumbar plexuses on the outside. The vessels, excepting the obturator, must pierce the fascia to get out of, the nerves to get into, the pelvic cavity, and through these small openings inflammation may possibly spread. But, as a rule, *suppuration above the fascia* is limited to the pelvic and abdominal cavities, that below to the perineum and ischiorectal fossa. Wounds of the latter two regions that involve this fascia have the added danger of pelvic inflammation; hence is seen the surgical importance of the pelvic fascia.

Between the *peritoneum*, which lines part of the pelvic floor and covers most of the pelvic viscera, and the "pelvic" and rectovesical fasciæ is a continuous layer of loose **subperitoneal connective tissue**, in which inflammation may spread readily and widely and lead to suppuration. This tissue is found *most abundantly* between the anterior bladder wall and the pelvis, about the outlet of the bladder, and, in the female, about the lower part of the uterus and the upper end of the vagina and between the folds of the broad ligament. Inflammation and suppuration in this tissue, known as **pelvic cellulitis**, is prevented from escaping through the pelvic floor by the pelvic fascia. Hence, as this tissue is continuous with the subperitoneal tissue of the iliac fossa, the *abscess* usually passes up over the pelvic brim to the iliac fossa and *points* in the inguinal region (pp. 307–8). Rarely it may open into one of the pelvic viscera or into the peritoneal cavity. In the male it may follow the vas deferens to the inguinal canal and scrotum. *In women* the inflammation and abscess are often found within the broad ligaments or beneath the peritoneum lining Douglas' pouch, between the uterus and the rectum. Clinically pelvic cellulitis is often accompanied by an inflammation of the pelvic peritoneum, *pelvic peritonitis;* the latter may also occur separately.

In **pelvic hematocele** the blood, if *intraperitoneal*, may trickle into Douglas' pouch, where it may become enclosed by peritoneal adhesions; or, if *subperitoneal*, it collects most often between the layers of the broad ligament. It often comes from a ruptured varicose ovarian vein or ectopic gestation. Pressure of the mass on the rectum may cause tenesmus. These collections of blood may, of course, become infected and suppurate, and in such a case can be opened through the vagina.

The Viscera of the Pelvis.

The Rectum.—As stated above (see Sigmoid Flexure, p. 357), that part of the rectum, formerly called the first portion, which is provided with a mesentery and extends from the left sacro-iliac joint, at the pelvic brim, to the middle of the third sacral vertebra, is now considered as a portion of the sigmoid loop, with which it is continuous. Between the layers of the mesentery of this portion of the sigmoid run the *inferior mesenteric vessels*, which *divide*, where the mesentery ends, into the two sets of bilateral *superior hemorrhoidal vessels*.

The rectum thus limited is more entitled to its name, rectum (straight), as it is not curved laterally, only anteroposteriorly. Of the *two parts* into which it is naturally divided, the *upper or pelvic portion*, about 12.5 cm. (5 in.) long, follows the curve of the sacrum and coccyx, upon which it lies; *the lower or anal portion* bends backward and downward just below the tip of the coccyx. It is important to bear in mind the *direction of the two curves* in examining or passing instruments into the rectum. The *axis of the anal canal*, if continued, meets the prostate near its apex or the rectovaginal septum. Hence, in introducing a

bougie, the nozzle of a syringe, a speculum, etc., the instrument should first follow the axis of the anal canal for 2.5 to 3.5 cm. (1 to $1\frac{2}{5}$ in.) upward and forward, and then be tilted so that its upper end is directed upward and backward in the curve of the upper part.

The *dividing line* between these two parts corresponds about to the point where the rectum pierces the pelvic floor. The anal canal is therefore entirely extrapelvic. In infants the lower end of the large gut is straighter and more or less vertical, and the upper part of what was formerly called the first portion of the rectum is in the abdominal cavity. On account of its more vertical position in childhood, together with its loose connections, the small size of the prostate and the liability to such exciting causes as worms and rectal polypi, *prolapsus ani* is especially common at this age.

The Pelvic Portion, or Rectum Proper.—Above the anal canal the rectum is dilated into a large *ampulla* extending forward to the apex of the prostate, and backward to the coccyx. This part is very *distensible*, and in cases of fecal accumulation may be enormously distended. Curious *foreign bodies* of large size have been found in this ampulla, such as, for instance, a bottle (Desormeaux), a glass tumbler, and an iron match box. When the rectum is *distended* in the male, *the bladder is raised* and pushed forward and the rectovesical pouch of peritoneum is elevated. Advantage has been taken of this fact *in suprapubic cystotomy* by distending the rectum by a rubber bag, inflated with air or water, to help raise the bladder above the symphysis.

It is *large enough to contain the entire hand,* which may be introduced, if not over eight inches in diameter, after a gradual dilatation of the sphincters under anesthesia. By a semirotatory movement it can be insinuated into the lower end of the sigmoid loop. It is said that a large part of the abdomen may be thus examined, even as far as the kidneys, owing to the mobility of the sigmoid. Yet the *practice is dangerous,* as the bowel may be torn, especially that part covered by peritoneum, and the sphincter may be permanently paralyzed. Moreover, the practical results are unsatisfactory, owing to the cramping of the hand. By means of a wooden lever, invented by Mr. Davy, introduced into the rectum, the common iliac vessels have been compressed against the pelvic brim to arrest hemorrhage in amputation at the hip joint.

Attachments.—Although the rectum, in passing through the pelvic floor, receives an investment from the rectovesical fascia, this investment is not so firm but that in rare cases all the walls of the gut are prolapsed at the anus. This *mobility* of the rectum is of use in excision of its lower part, for it allows the upper part to be drawn down so as to be sutured to the skin or to the edges of a healthy anal segment. In order *to free it for removal* the *levator ani muscle,* some of whose fibers are prolonged into and support the bowel, is divided, and the fasciæ forming the sheath of the muscle are separated from the rectum. To allow the upper part to be pulled down the *peritoneal attachment* must be loosened. This may be done by carefully stripping up the peritoneum from off the front and sides of the rectum and bluntly loosening the mesentery

behind. If it is necessary to pull down more, we must open the peritoneum, dividing it close to the rectum in front and at the sides, to avoid wounding the ureter, and as near as possible to the sacrum behind in dividing the mesosigmoid, to remove all the sacral glands and to avoid the bloodvessels, which run superficial to the muscle layers, for injury to these vessels means gangrene of the upper segment.

The rectum is loosely *attached by loose connective tissue* to the lower half of the sacrum and the coccyx, while in front it is more *closely attached* to the back of the *prostate and bladder* by firmer connective tissue, the *prostatoperitoneal aponeurosis,* connected with the rectovesical fascia. This aponeurosis, however, allows the separation of the rectum from the prostate and bladder, and, if traced upward, is found to be attached to the bottom of the rectovesical pouch of the peritoneum. *In the female* the rectum is attached to the vagina in front by a considerable amount of looser connective tissue.

Relations.—The relations of the rectum have a twofold importance, first in diseases of or operations on the rectum; second, because rectal examination is of the greatest importance in determining the condition of the organs in relation to it.

Relations to the Peritoneum.—As the rectum commences opposite the third sacral vertebra, there is no mesorectum, but the peritoneum, at first covering the front and sides of the bowel, is reflected from the sides along an oblique line descending from behind forward. It is finally reflected from the front of the rectum onto the bladder in the male, and onto the vagina, cervix, and uterus in the female, forming the *rectovesical and the rectovaginal pouch* (Douglas' pouch) respectively. The *distance* of the rectovesical pouches *from the anal orifice* is of importance in rectal operations, and measures about 7 cm. ($2\frac{3}{4}$ in.) when the bladder is empty, and considerably more when it is full. The distance of the similar pouch in the female (Douglas' pouch) from the anus is somewhat less.

In *complete prolapse* of the rectum of large size this *peritoneal pouch* may be protruded and may contain coils of intestine, which occupy it in the normal condition. *On the posterior rectal wall* the peritoneum does not come within 12.5 cm. (5 in.) of the anus. Thus ulcers and carcinomata situated anteriorly are more likely to invade or ulcerate into the peritoneal cavity, and in excisions of the rectum more of the bowel may be readily excised posteriorly than anteriorly. But, as we have seen, in the absence of adhesions we may detach the rectum from the peritoneum and draw it down as far as the commencement of the mesentery, where the peritoneum encloses the bowel. Above this point the bowel may be freed by dividing the peritoneum.

By rectal examination in the female we can feel anything abnormal, like a prolapsed ovary or a retroflexed or retroverted uterus, occupying Douglas' pouch, or, in the absence of these, we can feel the uterus in front and the ovaries at the sides, if the latter are enlarged or displaced. The retroflexed or retroverted uterus may so press upon the rectum as to favor constipation, cause tenesmus, and set up inflammatory or con-

gestive conditions in the rectum and an adhesion of the opposed peritoneal surfaces of the pouch. The close relation of the vagina and the anterior rectal wall accounts for the occurrence of tears into the rectum at childbirth. The fetal head has occasionally been forced through the thin rectovaginal wall and delivered per rectum.

Below the rectovesical pouch in the male we can feel the bladder, corresponding to the trigone, judge of its distention, and occasionally feel a calculus when present in the bladder. *Through the triangular area* of the bladder in contact with the rectum, and below the peritoneal pouch, the distended *bladder was formerly punctured* by a trocar almost painlessly, but, owing to the danger of infection, this method has been superseded by the suprapubic puncture. *Bounding the two sides of the triangular area* are the *seminal vesicles,* with the vasa deferentia internal to them. These can be readily felt when diseased (tuberculous) or distended, not so readily when normal. In violent attempts at defecation they may be pressed upon by the fecal masses and partly emptied, producing a mechanical form of spermatorrhea. Massage of the seminal vesicles as a therapeutic measure has been practised through the rectum. A stone impacted in the lower end of the *ureter* may possibly be felt through the rectum.

Below the palpable area of the *bladder* and the seminal vesicles we readily feel the *posterior surface of the prostate,* whose apex, 3 to 3.7 cm. ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.) from the anal orifice, is in front of the lower end of the ampulla. By rectal palpation we can feel the changes of size, shape, consistency, and sensitiveness in hypertrophy, inflammation, and abscess of the prostate. The *enlarged prostate* naturally *projects into the rectum,* and when of very large size may even cause obstruction to the passage of feces. We can therefore readily appreciate why defecation is painful in prostatitis, etc. At this part, too, a *prostatic abscess may open into the rectum,* and such an opening may result in a urethrorectal fistula.

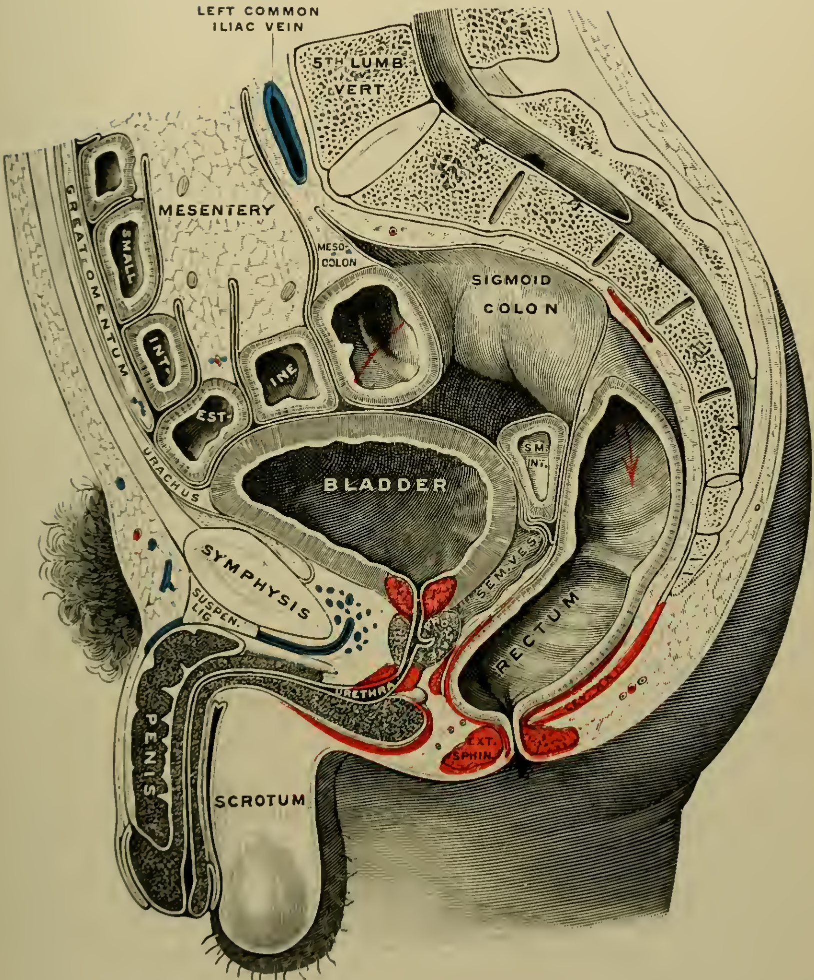
Below and in front of the apex of *the prostate* can be felt *the membranous urethra,* especially when occupied by a sound. The forefinger in the rectum, with its tip at the apex of the prostate, is used as a guide in Cock's operation (perineal section), and is useful in many perineal operations on the urethra, prostate, etc., and even in passing a urethral instrument in difficult cases.

The *bony points* palpable by rectal examination have been mentioned (p. 395). Their palpation is of use in determining the presence of any fracture, disease, or newgrowth connected with them. It is well to remember, in examining for suspected lesions high up in the rectum, that by having the patient strain, as at stool, especially in the standing position, 2.5 to 5 cm. (1 to 2 in.) more of the rectum can be palpated than otherwise.

The rectum is *not properly a reservoir for feces,* and in the healthy condition the presence of the latter stimulate it to contract. In some cases, especially those subject to habitual constipation, it may contain a large amount of feces, as often made out by digital examination, the nerves and muscles having become degenerate and ceasing to act.

PLATE XXXVIII

FIG. 140



Sagittal Section of the Lower Part of a Male Trunk, the Right Segment. (Gerrish, after Testut.)

The anal canal or terminal portion, 20 to 35 cm. ($\frac{4}{5}$ to $1\frac{2}{5}$ in.) *long,* is the *narrowest* part of the large intestine, although very *dilatable.* It is limited by the true skin below, the columnar epithelium above. Its lining consists of a mucocutaneous tissue which shows a gradual transformation from the true skin below to the typical mucous membrane above. The upper limit is the *anorectal line* of Testut or the free borders of the valves of Morgagni. About 4 to 5 mm. below the above line is an indistinct line, Hilton's *white line,* usually to be seen in the living, not on the dead. Even when not visible it can be felt as a depression, and hence is sometimes called the *anorectal groove.* It marks the division between the internal and external sphincters. The anal canal is quite distinct in its surgical relations from the rectum. The levator ani and its enclosing fasciæ are attached to and support its sides, which are in relation to the ischiorectal fossæ. In front lies the perineal body in the female, separating it from the lower end of the vagina, and the perineum in the male, separating it from the urethra.

In the male the anal canal forms the posterior wall of a triangle (urogenital), of which the surface of the perineum forms the base and the membranous portion of the urethra, where it adjoins the rectum, the apex. Through this triangle are made the various perineal incisions by which the bladder or posterior urethra, and sometimes the prostate and seminal vesicles, are reached.

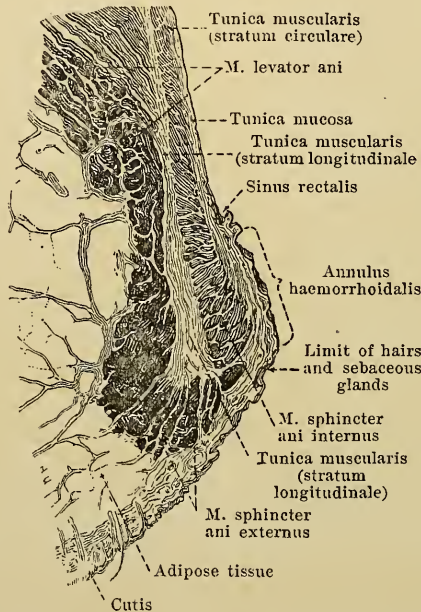
Structure of the Rectum.—The *longitudinal muscle fibers* are more uniformly spread out than in the rest of the large intestine, although, according to some, the three bands are continued as two bands, one in front and one behind, which broaden as they descend. The *circular fibers* are abruptly thickened (to 3 or 4 mm.) in the upper half of the anal canal to form the *internal sphincter.* The *external sphincter,* surrounding the anal orifice and the lower part of the anal canal, below the anorectal groove, is a striped or voluntary muscle.

The looseness of the *submucous* tissue is such as to allow the mucous membrane to be protruded or **prolapsed** at the anus on prolonged straining at stool or micturition. The greater looseness of this tissue in infants and children, the less support given by the fascial reflections from other organs, and by the undeveloped prostate or uterus, and the frequency of straining attending phimosis, constipation, or the irritation of worms and polypi, makes this accident especially *frequent in early life.* It may also be due to the relaxation of the parts attending persistent diarrhea. In adults it occurs mostly in old age when the muscular tone is weakened. When small it involves only the mucous membrane and tends to re-ascend, but may be held down by an irritated sphincter. When large all the coats of the bowel are apt to be involved and the rectovesical peritoneal pouch, and even coils of intestine, may be contained in the prolapse. The anal portion is rarely involved in a prolapse, as it is held so firmly by the levator ani muscle.

Certain obliquely transverse crescentic folds of mucous membrane, "**Houston's folds**" or "valves," not effaced but made more prominent by the distention of the rectum, are of importance, for they may *impede*

the passage of a bougie or a rectal tube, especially if the rectum is empty. Hence in giving a high enema first fill the rectum with fluid, and then

Fig. 141



Section through lower end of rectal wall, showing the relation of the external and internal sphincters and the extent of the mucous and cutaneous linings. The sinus rectalis is the so-called sinus of Morgagni. (Spalteholz.)

Fig. 144

Plaster cast of the rectum.

these folds will not impede the passage of the tube. Three such folds are usually present. One, the largest, on the right and anterior aspect,

PLATE XXXIX

Figs. 142 and 143.—Houston's Folds seen through Speculum, with Rectum Distended.

is just below the rectovesical pouch of peritoneum, or about 7.5 cm. (3 in.) from the anal orifice, and projects 1 to 3 cm. into the lumen of the gut, extending around half of its circumference or more. The other two are upon the left posterior quadrant, above and below the former, and the three are so arranged as to form a kind of spiral valve. They contain all the coats of the rectum except perhaps the longitudinal fibers, and in casts of the rectum appear as constrictions dividing the gut into sacculi (Fig. 144). The circular fibers are aggregated at the base of these valves and spread out in a fan-shaped way beyond them, not forming a complete sphincter, although the name of third or upper sphincter has been applied to one or another of them, usually the upper. This term has also been applied (O'Beirne) to a well-developed fold or valve at the junction with the sigmoid, opposite the third sacral vertebra. It is situated more or less anteriorly, contains the same aggregation of circular fibers, and more nearly occludes the caliber of the gut than the others (Tuttle).

Commencing at the upper end of the anal canal are five to twelve longitudinal folds of mucous and submucous tissue extending up for 1 to 2 cm. on the rectal mucosa. Between the lower ends of these columns are semilunar folds or valves whose upturned concavities form little *sinuses* or pockets. These are the **columns, valves, and sinuses of Morgagni**. Upon these columns are to be seen little protrusions, due to sac-like dilatations of the hemorrhoidal veins (Duret). The upper border of the folds or valves marks the change from mucocutaneous tissue to the columnar epithelium of the rectum, and represents the boundary between the anal canal and the rectum (anorectal line).

The mucous membrane is liable to *dysenteric inflammation and ulceration*, and the cicatrization of the ulcers may produce *stricture*. The liability to ulceration is greater the nearer we approach the anal canal. As the epithelium of the anus and anal canal is squamous or stratified polyhedral, and that of the rectum is columnar, an *epithelial neoplasm* of the former is an epithelioma (squamous-celled carcinoma), and of the latter a carcinoma or columnar epithelioma.

Vessels.—The *arteries* of the rectum are *from three principal sources:* the inferior mesenteric, the internal iliac, and the internal pudic. The middle sacral also supplies some blood to the rectum. The branches of the two lateral trunks of the superior hemorrhoidal pierce the muscular wall about 11 cm. (4½ in.) from the anus to form a *longitudinal network* in the submucous tissue. Hence *incisions* here should be lengthwise to avoid profuse bleeding. The arteries *communicate* freely in a plexiform manner near the anus and more or less so above. The *veins* have the same plexiform arrangement in the submucous tissue of the lower rectum and take the same course. *The blood of the rectum proper is returned by the superior hemorrhoidal* to the inferior mesenteric vein. The middle and inferior hemorrhoidal veins return the blood from the outer surface of the rectum and the anal canal to the vena cava. The anorectal line marks the boundary between the internal (superior) hemorrhoidal plexus above and the external or inferior plexus below.

The two systems are connected by anastomoses which in early life are very narrow. Hence congestion of the so-called hemorrhoidal veins of the rectum is apt to follow physiological or pathological portal congestion as well as venous congestion due to diseases of the heart, lungs, etc.

In addition to these causes, the tendency to varicosities of the hemorrhoidal veins, **hemorrhoids or piles**, is *in part due to* their dependent position, the lack of valves and any muscular and fascial support, and the pressure of fecal masses, etc. It may also be noted that the tributaries of the superior hemorrhoidal veins are liable to intermittent constriction where they pass through the muscular wall of the rectum, about 7.5 to 11 cm. above the anus. Hemorrhoids may also be symptomatic of pregnancy, ovarian or abdominal tumors, stricture of the rectum, prostatic enlargement, etc., as all of these conditions may obstruct the return of venous blood. Chronic constipation is a most prolific cause of hemorrhoids, pressing on the veins, irritating the rectum and causing straining at stool. These hemorrhoidal veins also communicate with those of the prostate and bladder.

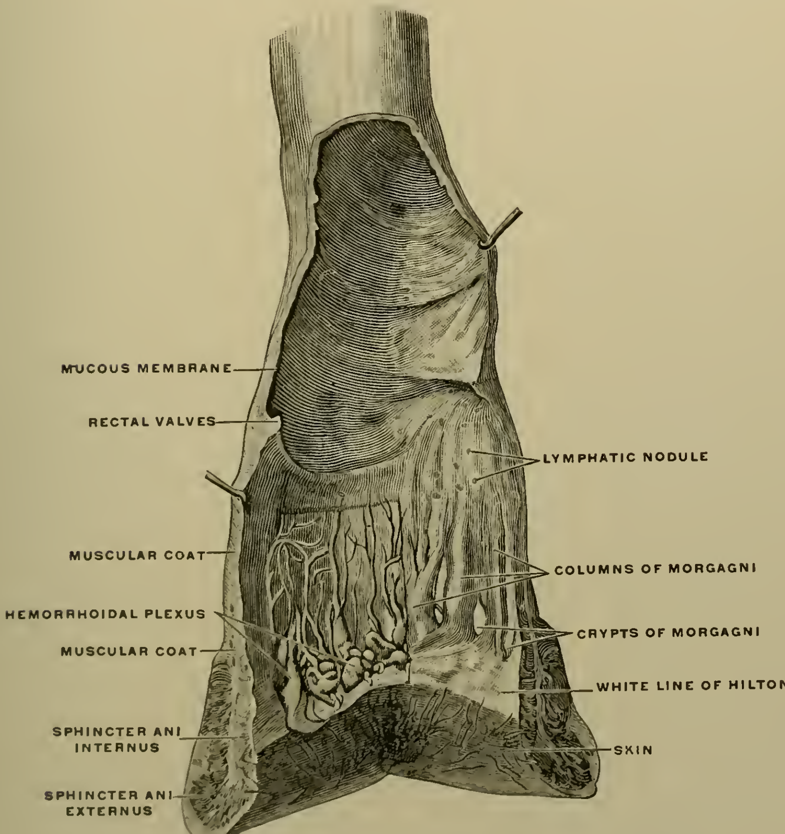
Hemorrhoids usually *commence* close to the point where the superior and inferior sets of veins anastomose at the *anorectal line*. Both sets of veins are usually simultaneously involved, but when the internal or external set is exclusively or predominantly involved the varicose enlargement is called *an internal or external hemorrhoid* respectively. A series of such swellings often surrounds the outlet of the bowel. Piles are usually confined to the submucous or subcutaneous tissues, so that they are *covered only by the mucous membrane* (internal piles) *or skin* (external piles). The mucous membrane or the skin on the surface of the swelling, due to the dilated and sometimes thrombosed veins, is chronically inflamed. The mucous membrane may be thickened, thinned, or ulcerated, in the latter case leading to "*bleeding piles;*" the skin is usually thickened, and develops into a flabby tab when acute inflammation is absent.

It should be borne in mind that the lower rectum thus furnishes an important *anastomosis* between the portal and caval veins. Infection or metastasis spreading by vascular channels from the rectum usually travels by the portal system to the liver.

The Nerve Supply.—The nerve supply of the rectum is from the inferior mesenteric and hypogastric sympathetic plexuses. *The anus is supplied by* the internal pudic nerve and the fourth sacral nerve, which accounts for the great pain and the wide distribution of reflex pain in anal fissure, inflamed hemorrhoids, etc., and for the paralysis, with incontinence of feces, that follows spinal injuries or diseases in the lumbar region or above. It is also mainly responsible for the close nervous association between the anus and the outlet of the bladder, which is supplied by the same nerves, so that on the one hand painful affections of the former may cause a frequent desire to urinate, and operations on the anus are especially apt to be followed by temporary retention of urine (vesical spasm); and on the other hand lesions of the outlet

of the bladder are often associated with rectal tenesmus. The *upper part of the rectum is but little sensitive,* as illustrated by the comparative painlessness of newgrowths, fecal accumulations, and the passage of instruments high up in the rectum. On the other hand, the anal canal is extremely sensitive.

Fig. 145



Longitudinal section through rectum, showing the interior. (Spalteholz.)

The Lymphatics.—The lymphatics of the rectum and the anal mucous membrane enter the sacral nodes in the mesosigmoid; those of the skin about the anus enter the supero-internal group of the inguinal nodes. Thus the anus has a blood, nerve, and lymphatic supply independent of that of the rectum.

The Anus.—The anus is an *oval,* not a circular, orifice at the lower end of the anal portion of the rectum. Hence specula, etc., should be introduced with the long diameter anteroposteriorly in the long axis of the anus. The anus *lies* in the median line 3.5 cm. ($1\frac{1}{2}$ in.) in front of the coccyx, just behind the middle of a line between the two ischial tuberos-

ities and only slightly farther from the lower border of the symphysis than from the tuberosities. In health it is tightly closed, and radiating from its margins there are numerous puckerings or small folds of skin, between which **fissures or ulcers** of the anus form and are often hidden. The *painfulness* of this affection is *due to* the reflex spasm of the sphincter, compressing the exposed nerve fibers at the base of the fissure or ulcer, which also prevents their healing. Hence *dilatation of the sphincter*, thereby temporarily paralyzing it and tearing the base of the fissure, gives relief and affords the fissure a chance to heal. Incision of the base of the ulcer, so as to divide part of the sphincter, produces a similar result. The anus may be torn by large hard stools during defecation, and some such tears may result in "painful fissure."

Near the anus we see the *external opening* in cases of **fistula in ano.** A common form is the result of *marginal abscesses,* superficial to the sphincters and lying merely beneath the skin and mucous membrane. Their *internal orifice* is generally found a little above the junction of the skin and mucocutaneous tissue, just within the grasp of the sphincter. The *upward extension* of an ischiorectal abscess is *resisted by* the levator ani muscle and the anal and rectovesical fasciæ covering it, between which and the external sphincter it finds a point of least resistance to extend toward the rectum, into which it usually opens between the external and internal sphincters, about 12 mm. ($\frac{1}{2}$ in.) from the anus. The abscess before opening may extensively undermine the mucous membrane, so that the resulting fistulous tract may extend upward, way above the point where it perforates the muscular wall. The internal opening, through the mucosa, may occur at the latter point or above. The cure of a fistula requires an incision uniting the internal and external openings, often involving the division of the external sphincter. Unless both sphincters are divided, incontinence of feces does not persist long. If the fistulous opening is into the anal canal only and not on the surface an "incomplete" or "blind" internal fistula results. (See also p. 483, Ischiorectal Fossa.)

Inspection of the anus is *of diagnostic importance.* Thus in cases of obstruction due to stricture of the rectum, greatly enlarged prostate, etc., the anus is patulous and flabby, while in fissure it is tightly closed.

Development and Errors of Development.—The *pelvic portion* of the rectum is *formed by* the blind caudal end of the hind gut; the *anal portion* by an invagination of the surface at the site of the anus. Normally *the septum between* them is absorbed so as to form a continuous canal, but abnormally it *may leave* an annular *constriction* at their junction, or it may persist and form an **imperforate anus.** In such cases the septum persists (1) as a *thin membranous septum* which bulges with the retained meconium and may be readily incised, or (2) as a *thicker partition* after division of which the rectal mucous membrane must be brought down to the surface to avoid stricture. Again, (3) there may be no anal invagination whatever, and in such cases the lower end of the rectal portion may or may not be absent. In infants with obstinate constipation digital examination of the rectum must not be neglected. If a careful

dissection through a median incision prolonged back to the coccyx and carried up in front of the coccyx and sacrum fails to discover the rectal pouch, an inguinal colostomy must be made.

In rare cases the rectum opens cutaneously *at some unusual point* (symphysis, prepuce, perineum, sacral, gluteal, or lumbar regions), and usually by a long canal with a narrow aperture. More often it opens into the genito-urinary tract, bladder, urethra, or vagina. Primarily the allantoic vesicle, from which the bladder and the posterior urethra are formed, was derived from and opened into the hind gut. The persistence of this connection may explain the rare opening between the rectum and the bladder. The rectal pouch in such cases lies so high up that inguinal colostomy must be resorted to. The opening into the bladder or urethra is usually small, and requires operative relief if possible. I have seen the opening into the vagina sufficient for the purposes of defecation, and this condition has been often reported. In the latter condition operation should be deferred until after puberty, when the increased size of the pelvis and perineum facilitates a plastic operation. Women have even married and borne children with a vaginal outlet to the rectum and without inconvenience from it. *Cancer* is most apt to be found within 5 to 8 cm. (2 to $3\frac{1}{4}$ in.) of the anus. Owing to its comparative painlessness it may be overlooked until hemorrhage or obstruction occurs. The relations of the rectum given above show to what structures it may extend. The sacral lymph nodes are first involved.

In **operations** for the removal of neoplasms or for resection of strictures of the rectum it may be approached through (*a*) the perineum; (*b*) the abdomen; (*c*) both (*a* and *b*); (*d*) through the vagina; or (*e*) from behind. In the latter approach *room may be gained* and the exposure of the parts increased by excising the coccyx. Or, following *Kraske's method* or one of its modifications, the lower end of the left half, or both halves, of the sacrum may be permanently or temporarily (osteoplastic method) resected. In these operations the lower border of the third sacral foramen should be the upper limit of the resection of bone, for if it is carried higher there is a risk of permanent paralysis of the bladder from interference with the third sacral nerves. These operations are carried out on the left side, for it is on that side that the lower or pelvic portion of the sigmoid loop lies. By division of the sacrosciatic ligaments or resection of their sacral attachments the *entire sacro-iliac notch is opened up*. When feasible we may save the anal portion, containing the sphincters, and use it by suturing the upper segment to it.

The Bladder.—The shape, position, and relations of the bladder, or urinary reservoir, depend upon age, sex, and the degree of distention of the organ. The average **capacity** is about a pint (400 to 500 c.c.), but may reach 1000 c.c. under normal conditions. When *distended*, in cases of retention, etc., the bladder has held as much as 3000 to 4000 c.c. of urine, and Tillaux reports a case in which it held 7 liters (7000 c.c.). On the other hand, a *contracted bladder* may contain no more than 10 to 20 c.c. ($2\frac{1}{2}$ to 5 drachms). The bladder of the male is somewhat more capacious than that of the female.

Shape and Position of the Adult Male Bladder.—*The form of the empty bladder* is a disputed point. Two forms are described: (1) the *systolic or contracted form,* in which the bladder represents a firm oval, whose cavity, on sagittal section, forms, with that of the urethra, a continuous curved slit; (2) the *diastolic or relaxed form,* in which the upper aspect presents to the intestines a cup-shaped concavity, and the cavity, with that of the urethra, presents a Y-shaped fissure on sagittal section. It is probable that the systolic form is the common one during life.

When moderately filled it is entirely within the pelvic cavity and has a *rounded form,* which may be flattened anteroposteriorly or transversely elongated by the pressure of the adjoining viscera. *As it becomes distended* it becomes *oval,* the convexity of the superior and postero-inferior surfaces is increased, the anterior surface is flattened, and the upper part of the latter, rising out of the pelvis, is in contact with the back of the anterior belly wall. This fact is taken advantage of in suprapubic cystotomy and tapping. *In distention* the upper or smaller end comes more and more in contact with the anterior belly wall, and may reach the umbilicus and even, it is said (Tillaux), the diaphragm. As the distended bladder is in direct contact with the abdominal wall, it always gives a dull or flat note on percussion. The distended bladder is *not quite symmetrical,* but deviates slightly to the right, owing partly to the rectum on the left side and partly to the greater size of the right half of the bladder. When distended so that its upper end is at the upper margin of the symphysis, its *long axis* is directed from the latter point to the end of the coccyx.

The **vesical outlet** (or internal urinary meatus) is on a horizontal line a little below the centre of the symphysis, about 2.5 cm. (1 in.) behind the latter and 5 to 6.5 cm. (2 to $2\frac{1}{2}$ in.) above the perineum. *In distention* the bladder is *displaced downward* as well as upward, depressing the perineum so that its outlet is at a somewhat lower level, while in cases of *prostatic enlargement* the outlet may be displaced upward, even above the symphysis.

The bladder lies behind the anterior pelvic wall, in front of and above the rectum in the male, the cervix uteri and the upper end of the vagina intervening in the female, and in contact with the small intestines and the sigmoid loop above and behind.

Relations to the Peritoneum (Figs. 140 and 146).—The *peritoneum covers* the entire superior surface, the lateral surfaces down to the line of the obliterated hypogastric artery, or a line extending from the urachus to a point somewhat below the summit of the seminal vesicles, and the upper part of the posterior surface, to the bottom of the **rectovesical pouch.** This pouch is usually filled with convolutions of the small intestine, separating the bladder and rectum, and it *reaches* to a point just below the upper ends of the seminal vesicles and about 2.5 cm. above the prostate (6.5 to 7.5 cm. from the anus). It forms *the upper limit* of the triangular area over which the rectum and bladder are closely adherent.

Normally the peritoneum lines the anterior abdominal wall down to

the symphysis pubis, from which it passes onto the upper end and superior surface of the bladder. As the *distended bladder* rises above the pelvis it *pushes up this parietal peritoneum,* which thus comes to cover the upper half of that part of the anterior bladder surface which extends above the symphysis, while the lower half of this surface is in direct contact with the anterior belly wall, just above the symphysis, without the intervention of the peritoneum. It is this arrangement of the peritoneum that renders suprapubic cystotomy or tapping a feasible and safe operation, for we can thus puncture or open a distended bladder above the symphysis without opening the peritoneum. Exceptionally the peritoneum is adherent to the pubes, so that it cannot be pushed up by the bladder. In operating on such a case, wounding of the peritoneum would be likely, but this wound could be sutured, the peritoneum carefully detached below and drawn upward, and the bladder then opened.

Theoretically, the lower half of that part of the anterior bladder surface above the symphysis should be devoid of peritoneum, no matter how high the bladder rises, but practically there is seldom more than 5 to 6.2 cm. (2 to 2½ in.) between the symphysis and the peritoneum, although the latter can be retracted still farther upward. When the bladder reaches half-way from the symphysis to the umbilicus there will be this 5 to 6.7 cm. of the anterior abdominal wall above the symphysis devoid of peritoneum and in direct contact with the anterior bladder wall. The use of Petersen's rubber bag, inflated in the rectum, prevents the bladder, filled with eight ounces (250 c.c.) of fluid, from extending downward and backward toward the perineum, and at the same time directly raises it and thus helps to bring it in contact with the anterior belly wall, but it has no special influence in raising the peritoneal fold above the symphysis. By the use of Trendelenburg's position gravity tends to bring the moderately filled bladder above the symphysis pubis and in contact with the anterior abdominal wall, so that the rectal bag may be discarded as unnecessary. In fact, little difficulty is found in opening the empty bladder, supra pubes, by the use of the Trendelenburg position.

The **anterior surface** and that part of the *lateral surfaces below* the limit of *the peritoneum* are separated from the fascia covering the obturator and levator ani muscles, of the anterior and lateral pelvic walls, by a quantity of *loose areolar tissue* whose meshes contain much fat. This tissue ensheaths the vesical vessels and occupies an area, the space of Retzius (**cavum Retzii**), more or less *triangular*, with its base directed downward, and shut in by the peritoneum above. The *looseness of this tissue* readily allows changes in dimension without disturbing the connections of the bladder, and it also *favors the rapid and wide spread of inflammation* following extraperitoneal wounds of the bladder with extravasation of urine. This tissue, or the subperitoneal tissue continuous with it, separates the distended bladder from the anterior abdominal wall, below the fold of the peritoneum. Hence it is *opened up in suprapubic cystotomy* and traversed by a trocar in tapping the

bladder, so that suppuration in this tissue, and in rare cases death, has followed the latter procedure. It is also *continuous* above and at the sides *with* the abdominal and pelvic *subperitoneal connective tissue,* hence an inflammation in it may become widely diffused.

The ureters *pierce the bladder* (Fig. 146) at the junction of the lateral and posterior surfaces, about 3.5 to 4 cm. ($1\frac{1}{2}$ to $1\frac{3}{4}$ in.) from each other, and the same distance above the prostate; just above the outer and upper limits of the triangular area of vesicorectal contact; and near to, although not in contact with, the rectum, so that a calculus in the lower end of the ureter may possibly be palpated through the rectum. The **vasa deferentia** *cross the lateral bladder wall* from before backward and above downward to reach the inner side of the seminal vesicles and form the sides of the above-mentioned triangular area on the posterior vesical surface. They *cross the obliterated hypogastric arteries,* and thence to the above triangular area they lie subperitoneally. They pass between the bladder and the ureters just where the latter pierce the bladder.

Rupture of the Bladder.—Rupture of the bladder is more serious when it involves in whole or in part the portion covered by peritoneum. Violence applied to the anterior belly wall may rupture the distended bladder without fracture of the pelvis or any external sign of injury. The bladder may be torn by bony fragments of a fractured pelvis or, rarely, in case of an injury of the rectum or vagina. When the bladder is distended by urine, in neglected cases of stricture, the urethra gives way, as a rule, before the bladder, and the urine is extravasated into the perineum. But rupture of the viscus has resulted in some rare cases from congenital closure of the urethra in infants and in neglected cases of retention of urine, especially in women and in prostatics. When the bladder is artificially overdistended it usually gives way laterally, below the peritoneal reflection (Tillaux), but *most ruptures* (85 per cent.) *intra vitam involve, in part, at least, the surface covered by peritoneum,* for it is this part that is thinnest and most distended when the bladder is filled. In *intraperitoneal ruptures* urine is extravasated into the peritoneal cavity, which it irritates, not when normal and fresh, but when abnormal or after becoming stagnant. Hence a primary condition of *treatment* is the free drainage of the bladder, and hence also the fatality of such ruptures unless the rent is repaired by suture and the extravasated urine is removed from the peritoneal cavity. The *injury is indicated by* inability to urinate, the urine passing through the rent into the peritoneal cavity, by the catheter removing only a little blood-stained urine, and by only a part of the fluid injected returning by the catheter. *Extraperitoneal rupture* is apt to be on the anterior wall, so that the urine escapes into the loose cellular tissue of the cavum Retzii. Cellulitis and abscess result, though recovery often ensues. **Stab or bullet wounds** take the same clinical course, according as they are intra- or extraperitoneal, except that a small bullet wound, like the puncture of a small trocar, may become at once plugged by the mucous membrane and the muscular contraction of the wall, thus preventing extravasation.

Fixation of the Bladder.—The reflections of peritoneum onto the bladder, known as its *false ligaments, steady it* without fixing it, while the bands of thickened rectovesical fascia, reflected onto its base and known as its *true ligaments, anchor this part.* It is still further *fixed in position by its attachment* behind to the rectum in the male and the uterus and vagina in the female, and by the connection of the ureters, urethra, prostate and the fibromuscular cord of the urachus.

Malposition.—In spite of these various means of anchoring the bladder, and on account of the laxity of the attachments, it has been *found in* inguinal, femoral, and some forms of pelvic *herniæ,* especially in men over fifty. In inguinal and femoral herniæ the part herniated may be entirely extraperitoneal (in 75 per cent.) or in part intraperitoneal. An abnormally *high position* of the bladder may be due to prostatic, rectal, or pelvic tumors.

The Bladder Wall.—The bladder wall varies in *thickness* from 3 mm. ($\frac{1}{8}$ in.), when moderately distended, to 12 mm. ($\frac{1}{2}$ in.) or more when contracted. The anterior wall and trigone are somewhat thicker than the rest of the bladder. When there is obstruction to the escape of urine the *bladder muscle hypertrophies* from undue exercise, like other muscles. In such cases the interlacing network of the internal layer of fibers is thickened and appears as distinct intersecting ridges beneath the mucous membrane (*the fasciculated bladder*). The bladder wall in the interspaces of this network is thinner and weaker, and its mucous membrane may become protruded or herniated in the form of sacculi, by the increased intravesical pressure (*the sacculated bladder*). One or several of these sacculi may become so enlarged as to allow urine to stagnate and decompose, phosphatic deposits to form and collect, and calculi to develop or become hidden (*encysted calculi*). When a calculus, previously contained in the bladder, slips into a sacculus the symptoms suddenly subside and the stone may no longer be felt by the searcher. Digital rectal examination may sometimes reveal the presence of such calculi. The ridges of a fasciculated bladder may become encrusted with phosphatic deposits and give rise to possible errors in diagnosis in the use of the searcher. When only one sacculus is developed it may become enlarged, even to the size of the bladder, and give rise to the erroneous designation "*double bladder.*" Below and in front the longitudinal fibers of the *external layer*, known from its action as the *detrusor urinæ muscle,* pass on each side in front of the prostate to the back of the pubic bones as the *vesicopubic muscle,* while superiorly the longitudinal fibers are continued into the urachus. The *circular fibers of the middle layer* are aggregated near the vesical outlet, where they are known as the *internal sphincter* of the bladder, although Henle has shown that their action is to empty the bladder of the last drops of urine, the real internal sphincter being the circular fibers of the upper prostatic urethra.

The entire bladder is *invested by the rectovesical fascia,* which is much thicker at its lower part. The *elastic submucous layer* is intimately connected with the mucous membrane, which it loosely connects with the muscular layers, except over the trigone, where the three layers are closely

adherent, a fact of importance, for otherwise the trigonal mucous membrane would be prolapsed into and block up the urethral orifice during micturition. As a result of this adhesion the mucous membrane of the trigone is always smooth, while that of the rest of the bladder is thrown into rugæ when the bladder is empty. The density of the trigonal mucosa prevents free swelling and partly accounts for the pain from inflammation of this area. The laxity of the mucous membrane elsewhere allows of the great changes in the size of the viscus. The mucous membrane is rose colored, but over the trigone it is somewhat paler.

Blood and Nerve Supply.—The blood derived from the *three vesical arteries* and small twigs from the arteries of the neighboring parts (uterine and vaginal in the female) is returned by the veins into the internal iliac vein. When inflamed the mucous membrane is deeply injected and bleeds readily. The *veins form plexuses* around the lower end or base of the bladder, which are connected with those of adjacent parts, especially with those of the prostate in the male, forming the *vesicoprostatic plexus.* Hence in enlargement of the prostate this plexus becomes varicose (*vesical hemorrhoids*), from the pressure of the enlargement upon it. In such cases the varicose veins project into the bladder near its outlet, where they are *liable to bleed* spontaneously or from the use of instruments, and they produce a swelling and congestion of the mucous membrane here which *causes the frequent micturition.* The bleeding may temporarily relieve the congestion and the symptoms caused thereby. Bleeding from the bladder usually indicates tumor or stone.

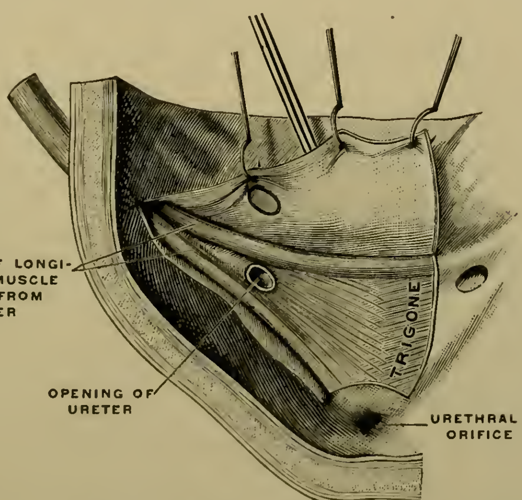
The **lymphatics** of the bladder empty into the external iliac and hypogastric nodes and those at the bifurcation of the aorta. Lymphatics are wanting in the mucous membrane.

The *nerves* are derived from the *hypogastric plexus, supplying the muscle fibers,* and from the *third and fourth sacral nerves supplying principally sensation.* The mucosa of the greater part of the bladder is only slightly sensitive, as may be observed in the passage of a sound or searcher; that of the trigone, especially at the ureteral openings, and in the neighborhood of the outlet is much more sensitive. When the bladder is inflamed its mucosa, especially that near the outlet, is much more sensitive, as seen in cases of cystitis or in stone. In the upright position the stone gravitates to the highly sensitive trigone, hence the pain is more severe and micturition is more frequent during the day than at night. In micturition the stone is forced against the outlet, causing great pain and perhaps suddenly checking the flow of urine. Frequent micturition is usually due to an irritation through the sensory nerves (third and fourth sacral), setting up a reflex motor impulse which passes from the last two dorsal and upper lumbar segments through the hypogastric plexus. Sudden distention of the bladder causes acute pain, but it may become gradually distended with only a sense of discomfort.

When the *nerves* supplying the bladder are *paralyzed* from injury or disease of the cord, *distention ensues* from lack of power to empty it, and the consciousness of the bladder being distended is lost. Thus we

have *retention of urine,* but in time the outlet is opened up by the pressure and overflow or *incontinence of urine* occurs, the bladder remaining distended. In the child incontinence (usually nocturnal) generally occurs from irritability, not from distention. Retention may also occur from obstruction, due to stricture, enlarged prostate, etc., but however it occurs, *long-continued overdistention produces temporary or permanent paralysis* by overstretching the muscular fibers. Thus the urine flows from the catheter without force, and catheterization must be continued for some time. The sudden complete evacuation of all the urine in an overdistended bladder, by removing the pressure on its bloodvessels, causes such a relaxation and overfilling of them that oozing of blood occurs into the bladder. Hence the advice not to completely empty at once an overdistended bladder. In cases of repeated or long-continued overdistention the *ureters become greatly distended.* (See Ureters, p. 388.)

Fig. 146



Trigone of the bladder with a flap of mucosa dissected up from the greater part of it, showing the mode of termination of the ureter and the prolongation of the bundles of its longitudinal muscle fibers along the boundaries of the trigone. A grooved director leads to post-trigonal pouch. (Testut.)

The Interior of the Bladder.—The interior of the bladder presents *three orifices:* the outlet or *internal urinary meatus,* at the most dependent part of the bladder in the erect position and at the apex of an equilateral triangle, the trigone, whose two other angles are formed by the *orifices of the two ureters,* each 18 to 25 mm. (¾ to 1 in.) from the outlet. The vicinity of the ureteral orifice is congested or ulcerated in tuberculosis of the kidney on the same side. Connecting the two ureteral orifices and bounding the base of the trigone is an arched elevation (*plica ureterica*), due to a band of muscle fibers continued from the ureters. In chronic cases of obstruction, as in cases due to prostatic hypertrophy, this ridge forms the anterior boundary of the depression known as the *post-*

prostatic pouch (*fossa retro-ureterica*). The longitudinal mesial ridge of mucous membrane, the *uvula vesicæ* (or *uvula of Lieutaud*), passes from the middle of the above ridge to near the outlet, where it is most prominent. It is especially marked in old age, and corresponds to the middle portion of the prostate.

The ureters, reaching the bladder 3.5 to 4 cm. ($1\frac{1}{2}$ to $1\frac{3}{4}$ in.) apart, pass so obliquely through its wall for 12 to 18 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) that their *oblique passage serves the purpose of a valve*, preventing reflux from the bladder and acting more perfectly the fuller the bladder. Under pathological conditions the valvular action may be imperfect, allowing backward flow, and Lewin's experiments on rabbits would indicate that the same may occur under normal conditions when the bladder is not too full.

The Female Bladder.—The female bladder has its *longest diameter transversely*, owing to the greater width of the female pelvis and the presence of the uterus and vagina behind it. Owing to the less depth of the symphysis, the *outlet is relatively lower, i. e.*, behind the lower end of the symphysis; and, there being no prostate, it is a trifle nearer the symphysis and *very distensible*. This distensibility of the outlet, in connection with the shortness and dilatability of the urethra, enables us to explore the female bladder with the finger, to remove stones and foreign bodies through the urethra, and to more readily examine the interior of the bladder with the cystoscope. For the same reason stone and cystitis are less common, and foreign bodies, introduced per urethram, more common, than in the male. The *peritoneum does not descend so low* on the posterior surface in the uterovesical pouch, which separates the bladder from the body of the uterus, as in the male in the recto-vesical pouch. Below this pouch the *bladder is in contact with* the cervix uteri and the upper half of the vagina. A slight continuation of the subperitoneal connective tissue extends between the bladder and the cervix, thus facilitating their separation in removal of the cervix or uterus, if the operator follows this tissue layer. The close *relation of the bladder and the vagina* explains the frequency of *vesicovaginal fistulæ*, which are apt to follow a tear or sloughing of the anterior vaginal wall, the result of difficult labor. The **ureteral orifice** is 2.5 to 3 cm. (1 to $1\frac{1}{4}$ in.) below the cervix uteri and opposite the middle of the vagina, hence calculi can be felt per vaginam in the lower ends of the ureters. The latter are also in danger of being injured in operations on the cervix.

The Bladder in the Infant.—The bladder in the infant is *pear-shaped*, with the small end above and in front at the urachus, which represents the stalk of the pear. At birth the *outlet* is behind the upper margin of the symphysis and the *bladder is largely in the abdomen* and entirely above the level of the symphysis, only about one-half of the organ being below the pelvic brim, as the pelvis is small and occupied mainly by the rectum. Hence in perineal lithotomy in young children the knife must be directed well upward to reach the bladder. The position and relations of the bladder begin to change when the child commences to walk, and are about like those of the adult at the age of six years. Before this

condition is reached the *anterior wall* of the bladder, uncovered by peritoneum, is *in contact with the anterior abdominal wall* and readily accessible to suprapubic operations or puncture. In young male children the *rectovesical fold extends* nearly or quite to the base of the very small prostate, which brings it very close to the vesical outlet; in fact, at birth it reaches this level. The bladder is more movable owing to the undeveloped prostate, etc. The *bladder wall* is so *thin* that it is said that a "click" may be elicited through this wall from the pelvic bones, in sounding for stones.

Formation.—The bladder, female urethra, and the prostatic and membranous parts of the male urethra are formed by that portion of the *allantoic vesicle* which lies within the body cavity and extends between the hind gut and the umbilicus. The upper part of this is normally obliterated to form the urachus, the lower part is partitioned off from the cloaca, or common opening of the urinary and alimentary tracts, by the growth of a partition which forms the perineum.

Malformations.—Faulty growth of this partition may lead to fistulæ between the rectum and bladder or urethra. *Exstrophy*, or congenital hiatus of the bladder, and *patency of the urachus* have been referred to under Anterior Abodminal Walls (pp. 282 and 290), rectovesical fistula under Rectum (p. 417). These are *congenital conditions*, depending upon errors of development.

Newgrowths.—Newgrowths of the bladder *include* epithelioma, fibroma, myoma, and, in early life, sarcoma. They are especially apt to take on a villous form and to involve, like other pathological processes, the lower part of the bladder, where they may occasionally obstruct the outlet and bleed freely. The contents of the posterior urethra can pass readily into the bladder, those of the anterior urethra only by injection under high pressure. *The bladder may be reached and opened* for exploration, drainage, or the removal of stone, foreign bodies, tumors, etc., by *two routes:* (1) *perineal* (see Perineum); (2) *suprapubic* (see pp. 285 and 419).

The Prostate.—The prostate (Figs. 140, 147, 156, 157, and 158) is an elastic, contractile organ *of the male generative system* which embraces the vesical outlet and encloses the first (prostatic) portion of the urethra, in which parts of the urinary system the effects of its pathological changes are chiefly noticed. That it belongs to the generative rather than the urinary organs is shown by its small size during childhood, its sudden growth at puberty (together with the testicles, etc.), its atrophy or small size after castration and in eunuchs, and its anatomical relations with the ejaculatory ducts and the prostatic utricle. These facts led to the suggestion, by J. William White, of castration for prostatic hypertrophy.

In **size** and **shape** the adult prostate is not unlike a Spanish chestnut, *measuring* about 3 to 3.5 cm. ($1\frac{1}{4}$ in.) from base to apex, 3.5 to 4 cm. ($1\frac{1}{2}$ in.) transversely, and 2.5 cm. (1 in.) from before backward, and *weighing* 6 drams. When the gland is appreciably larger (according to Sir H. Thompson, when it weighs one ounce and measures two inches transversely), **hypertrophy** or **enlargement** of the prostate is said

to exist. This occasionally occurs earlier, but in about one-third of all men over fifty years it is present in some degree, and in 10 per cent. of males over fifty-five it is of pathological importance. Its cause is unknown, but various theories attribute it to (*a*) arteriosclerosis (Guyon); changes compensatory to (*b*) primary changes in the bladder (Harrison); or (*c*) to deterioration in the prostatic secretion; (*d*) a growth analogous to uterine fibromyomata (Thompson); (*e*) infection (especially gonococcal), etc. It may principally affect any of the component elements of the gland or the lateral or median portions of it. In addition, prostatic enlargement may be due to prostatitis, abscess, tuberculosis, carcinoma, etc.

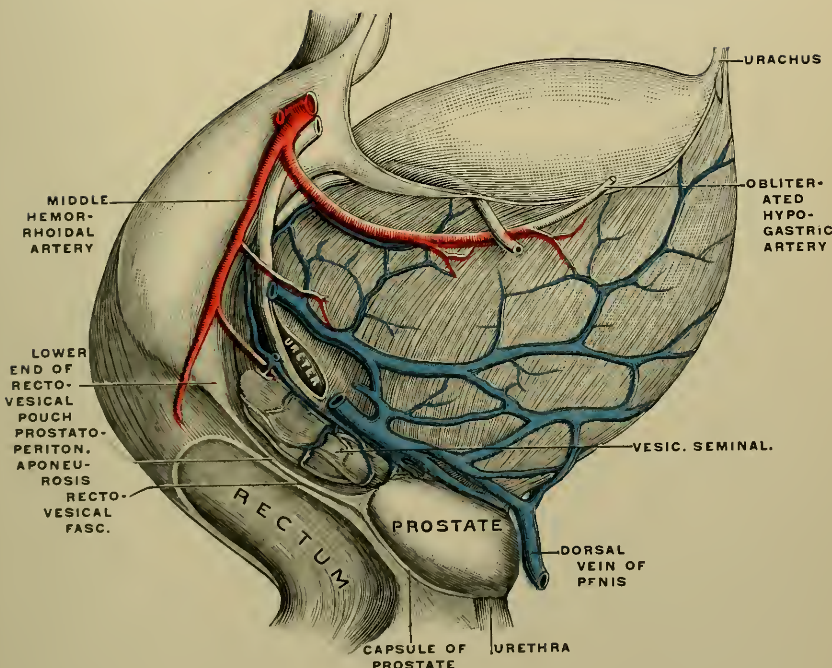
The **anatomical effects of enlargement** are to lengthen and compress the prostatic urethra, to increase its curvature in many cases and sometimes to produce a lateral curvature (due to the greater enlargement of one side), and to cause the gland to project in the directions of least resistance, backward into the rectum and upward into the bladder, so as to raise the outlet above the most dependent part of the bladder and lead to the formation of the postprostatic pouch, below the level of the vesical outlet. The **physiological effects** are: (1) increased *difficulty* of micturition, due to compression of the urethra and obstruction of the vesical outlet by a prominent middle portion and by raising the outlet; (2) increased *frequency* of micturition, due to congestion of the lower end of the bladder from the pressure of the enlargement on the vesicoprostatic plexus; and (3) the inability to empty the bladder owing to the elevation of the vesical outlet and the presence of the postprostatic pouch, resulting in the presence of residual urine and the danger of decomposition of the stagnant urine.

As a rule the enlargement implicates the prostate pretty uniformly. If the lateral lobes are chiefly involved, the gland may attain considerable size without causing serious symptoms, whereas a trifling enlargement of the middle portion or of the "pre-spermatic group" (Albarran) of glands beneath the floor of the vesical outlet may cause marked obstruction. Occasionally a pedunculated median growth projects into the bladder and obstructs the outlet like a ball valve.

We can clearly distinguish **two lateral lobes** of the prostate, especially when we look at the posterior surface where they are separated by a shallow furrow. This widens out above into a wedge-shaped furrow, which is continuous with a transverse furrow or slit at the junction of the posterior surface and the base, in which the ejaculatory ducts enter the prostate. Between this latter furrow and the course of the ejaculatory ducts posteriorly, the urethra in front and the diverging upper ends of the lateral lobes on the sides, lies the "**middle portion**" or so-called "middle lobe." When normal it is scarcely an anatomical entity, but in some cases of prostatic enlargement this part may be principally or exclusively enlarged. In such cases, as it corresponds to the uvula vesicæ, it projects into and obstructs the vesical outlet, occasionally as a pedunculated tumor. The *base* of the prostate, surrounding the vesical outlet, receives the latter in a funnel-shaped depression somewhat in front

PLATE XL

FIG. 147



Relative Position of the Bladder, Ureter, Rectum, Prostate, Seminal Vesicles, Vas Deferens, and their Vessels, viewed from the right side. (Joessel.)

of its middle. The prostatic urethra traverses the gland from base to apex a little in front of its centre; rarely it merely grooves the anterior surface or, in other cases, passes more posteriorly.

The **position** of the prostate is such that its **axis** from base to apex is nearly vertical in the erect position. The **apex**, resting upon the deep layer of the triangular ligament, lies 12 to 18 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) behind and a little below the lower end of the symphysis, and 3 to 3.7 cm. ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.) from the margin of the anus. The *posterior surface* forms an angle of 45 degrees with the horizon; the *anterior* is nearly vertical.

Of the **relations** of the prostate, that of the *posterior surface* to the anterior aspect of the lower end of the pelvic portion of the *rectum* is of especial importance, for it allows of easy examination through the rectum, the two being separated only by a little loose connective tissue in addition to the capsule of the prostate. It is through the rectum that we can readily distinguish enlargements of the prostate unless there is hypertrophy of the "middle lobe" alone, when nothing can be made out by rectal touch. The lower ends of the *seminal vesicles* and the ampullæ of the *vasa deferentia* are in relation with the posterosuperior aspect of the "middle portion." On the *sides* it is in relation with the *levator ani* muscles, including their inner and lower borders, and in "lateral prostatectomy" we find that it is this muscle and its ensheathing fasciæ which separate the prostate from the ischiorectal fossa. The *base* of the prostate is in relation with the bladder for a considerably greater distance behind than in front of the vesical outlet. It is held fixed in position by the parts mentioned in relation with it, viz., bladder, rectum, ejaculatory ducts, urethra, levator ani, deep triangular ligament, and its outer fibrous capsule, formed of the rectovesical fascia and continuous below with the deep triangular ligament.

This **capsule** explains in part the course of *prostatic abscess, i. e.*, that they seldom extend upward and open into the pelvis, for this course is resisted by the pelvic fascia reflected from the pelvic floor to the base of the prostate to form its capsule. **Prostatic abscesses** extend in the directions of least resistance, and accordingly open most often into the urethra, next in order of frequency into the rectum. (See Relations of the Prostate.) Less frequently they open in the perineum, which they reach by running along the side of the rectum, for the dense triangular ligament prevents their passage more anteriorly. They may be a cause of peri-anal fistula, and such fistulæ are apt to recur after the ordinary fistula operation. When they perforate both the urethra and rectum a *urethrorectal fistula* may result. Prostatic abscess is the result of a *prostatitis*, usually of gonorrheal origin. Such an inflammation may not go on to abscess formation, but stop short of it with enlargement and tenderness of the gland, readily felt by rectum, and with frequent, painful, and difficult micturition. The *firmness* of the capsule goes to explain the severe *pain* in acute prostatis.

Between this capsule and the organ itself, surrounded by its own true capsule, is found the **prostatic plexus of veins**, most marked at the sides and in front, receiving at the latter part the dorsal vein of the penis,

through the pudendal plexus. The plexus also connects with the neighboring veins, the hemorrhoidal of the rectum, and the vesical, especially with the latter, with which it forms the vesicoprostatic plexus, in the groove between the prostate and the bladder. *Phleboliths* occur more commonly here than in any other veins. As these veins are cut in lateral lithotomy and other operations they may afford an entrance for septic matter in cases of pyemia following such operations. These veins empty into the internal iliac vein.

In **structure** the prostate is a *musculoglandular* organ. The *glands* are chiefly at the posterior and lateral parts of the organ, and open in the floor of the sinuses of the prostatic urethra. They sometimes contain pathological concretions. The anterior part of the organ in general contains but few glands. The *muscle tissue* is largely of the unstriped variety, but a certain amount of *striped fibers* lie in front of the prostatic urethra and surround the lower part of it, forming the *external sphincter vesicæ,* continuous below with the compressor urethræ muscle. The *unstriped fibers* are arranged as follows: (1) They surround the urethra, forming the **internal sphincter** of the bladder at the upper end of the urethra, where they are derived from the deeper layer of the muscle of the trigone; (2) they are condensed into a *musculofibrous sheath,* between which and the fibrous capsule lies the venous plexus; and (3) they form part of the proper *stroma* of the organ. The fibrous and muscular tissue of the anterior and posterior commissures forms a median anteroposterior septum or bridge of tissue that unites the lateral lobes in front of and behind the urethra, which it encloses and blends with. According to some (Freyer) the inner sheath of the gland is formed by the fibrous sheaths of the two lateral halves of the embryonic prostate, which join together, enveloping the urethra. This explains how, in hypertrophy, each lateral lobe in its sheath may be shelled out without injury to the urethra or the ejaculatory ducts, which latter do not penetrate this sheath.

The prostate may be reached for *operation* through the perineum or through the bladder, suprapubically. It is only separated from the ischiorectal fossa by the levator ani muscle and its two investing fasciæ, the anal and rectovesical. From below it may be most freely exposed by an angular or curved transverse incision in front of the rectum (Zuckerkandl's incision), or an anteroposterior incision curving around the left side of the rectum (v. Dittel's incision).

The two ejaculatory ducts (Figs. 156 and 158) are the outlet into the prostatic urethra of the seminal vesicles and the vasa deferentia, by the junction of which, on either side, they are formed near the posterosuperior margin of the prostate, 6 to 8 mm. behind and below the vesical outlet. They *pass* thence downward and forward behind the middle lobe and between it and the lateral lobes of the prostate, and then along the sides of the prostatic utricle to *open* on either side of the mouth of the latter on the verumontanum, in the floor of the prostatic urethra. They are about 18 to 20 mm. ($\frac{3}{4}$ in.) *long,* converge slightly, and decrease in *size* from above downward.

In sagittal *incisions* in the prostate behind the urethra, not exactly median in position, one of these ducts is wounded. This is objectionable, especially in young subjects, as it may result in closure of the duct. An oblique radiating incision, as in lateral lithotomy, is less likely to wound them. *Inflammation* may extend through the duct to the vas deferens and thence to the epididymis from the bruising of the aperture of the duct in the extraction of a stone or a fragment of a stone or in the passage of an instrument, or from the extension of a urethritis. This and not metastasis is the usual origin of epididymitis, as is indicated by the slight enlargement and tenderness of the vas, although attention is not usually called to it by any marked symptoms. The injection into the prostatic urethra of solutions of nitrate of silver, etc., in cases of derangement of the sexual function is intended to act upon the openings of the ejaculatory ducts.

The Seminal Vesicles.—The two vesiculæ seminales (Figs. 140 and 147) are symmetrically *placed* on the two sides between the base of the bladder and the front of the pelvic portion of the rectum. They *extend* from the ejaculatory ducts, at the base of the prostate, upward, backward, and outward for about 4 to 5 cm. (2 in.), at an angle of 50 to 60 degrees with the horizon. Their position varies somewhat with the condition of the bladder and the rectum. Posteriorly their fibromuscular capsule is connected with that part of the rectovesical fascia which forms the fascial covering of the rectum. The lower ends of the vesicles are *palpable* through the rectum, above the base of the prostate, especially if the hand presses the surface about the anus strongly upward and the prostate is not enlarged. The seminal vesicles are more readily palpated when the bladder is full and when they are enlarged or hardened by disease. By the finger in the rectum we can press downward the contents of the vesicles into the prostatic urethra and thence externally. The same result may follow the passage of large, hard, fecal masses through the rectum, which may cause a young male neurasthenic to fancy he has spermatorrhea. They are sometimes massaged through the rectum as a therapeutic measure in chronic vesiculitis. The *upper fourth* of the seminal vesicles is covered behind by the peritoneum of the rectovesical pouch, which separates this portion from the rectum. This pouch sinks somewhat lower in the space between the vesicles.

Anteriorly the capsule of the seminal vesicles is connected by loose tissue with the base of the bladder. The vesicles, together with the ampullæ of the vasa deferentia along their mesial borders, lie along the lateral borders of the *trigone* of the bladder and the fossa retroureterica, so that in distention of the bladder the latter fossa projects between the seminal vesicles. The *upper ends* or bases of the vesicles are 6 to 7 cm. apart; they approach the lateral pelvic walls and overlap the lower ends of the *ureters* just before the latter pierce the bladder.

The vesicles are loosely connected with their *capsules* from which they are readily shelled out. When so shelled out we see that their lobulated appearance is due to the *convolutions* of a blind tube, about 10 cm. (4 in.) or more long, and to numerous blind sacculi and lateral

branches. The *capsule* is continuous with that of the prostate and with the rectovesical fascia, and contains several scattered muscle fibers. Enclosed within its capsule each vesicle presents an elongated triangular *shape,* the lower and smaller end of which opens by a free *aperture* into the lateral wall of the lower end of the ampulla, of which it is a sacculated appendage. The seminal vesicles vary much in *size* not only in different persons, but on the two sides of the same person. One or both vesicles have been found wanting, the latter condition usually in anorchids.

The vesicles *secrete* an albuminous fluid, which usually contains a few spermatozoa which have wandered there by their own motility, for it is now thought improbable that they serve as reservoirs for the semen. The contents of the vesicles add to the bulk of the fluid ejaculated.

The vesicles from their position, about the centre of the pelvis, are well protected from *injury,* which rarely affects them. *Inflammation* (usually gonorrheal) may extend into the seminal vesicles from the prostate through the ejaculatory ducts, and, if an abscess forms, the relations of the vesicles show that it may break into the bladder, rectum, or peritoneal cavity, and that it may involve the vas, the prostate, or the ureter. Tuberculosis of the seminal vesicles is not uncommon and forms one of the varieties of genito-urinary tuberculosis. It is usually an extension from neighboring parts (prostate, epididymis).

The seminal vesicles may be *exposed* and *removed* through perineal incisions similar to those used to expose the prostate, separating the latter from the rectum until the vesicles are reached.

The Vas Deferens (Fig. 147).—This continuation of the epididymis, or efferent duct of the testis, extends from the globus minor to the ejaculatory duct. **In the scrotum** it lies behind the testis and internal to the epididymis, thence it extends upward to the external ring as one of the constituents of the **spermatic cord,** behind and internal to the other constituents of the cord. In this position it is readily *felt* and avoided in operations for varicocele or hernia. It is readily felt as a uniform, firm, round, whipcord-like structure. Its firmness is due to the thickness of its walls as compared with the size of the lumen. When affected by tuberculous disease it is characteristically nodular. In cases of *inversion* of the testis its position is reversed, lying in front of the testis and the other elements of the spermatic cord.

At the *external abdominal ring* it lies behind and internal to the neck of the sac of an oblique inguinal *hernia* and external to that of a direct inguinal hernia. It may become adherent to the coverings of a hernia, especially in cases of long standing. After entering the *abdomen* through the internal ring it soon diverges from the spermatic vessels and, looping above the arch of the deep epigastric artery, *enters the pelvis* near the iliopubic eminence. It then runs backward and downward on the lateral pelvic wall, and thence onto the posterolateral aspect of the *bladder.* In this part of its course it *crosses* the external iliac vein, obturator vessels and nerve, and the obliterated hypogastric artery.

On the bladder it lies on the vesical side of the obliterated hypogastric artery and the lower end of the ureter, separated from the latter by a layer of perivesical fat 1 cm. ($\frac{1}{2}$ in.) thick. Thence it bends down on the mesial side of the ureter onto the base of the bladder, where it lies between it and the rectum, adjacent and internal to the vesiculæ seminales. Here it becomes enlarged and somewhat sacculated as the *ampulla*, whose relations are similar to those of the seminal vesicles already described (q. v.). Near the base of the prostate and the inferior angle of the external trigone it narrows down and is joined by the seminal vesicle to form the ejaculatory duct.

The entire *pelvic portion* of the vas, except that at the base of the bladder, is *subperitoneal* and quite closely attached to the peritoneum, so that when the latter is raised it tends to follow it.

The *infection* from a urethritis may extend along the vas to the epididymis, giving rise to epididymitis. In such cases the vas becomes swollen to the size of a leadpencil and tender, but the inflammation of the vas speedily subsides and generally leaves no trace. The ampulla of the vas may be palpated, exposed, and operated upon in the same way as the seminal vesicles.

The *artery* of the vas deferens, derived either from the superior or one of the inferior vesical arteries, forms an important *anastomosis* with the *spermatic* artery at the lower end of the epididymis, which is sufficient to nourish the testis when the spermatic artery is ligated in the operation for varicocele.

THE FEMALE PELVIC GENITAL ORGANS.

The Uterus.—The uterus lies within the pelvis between the bladder and the rectum, and, together with its lateral or broad ligaments, divides the pelvic cavity into an anterior or uterovesical and a posterior or uterorectal compartment. Its size and shape vary with age and many physiological and pathological conditions. In **shape** it is pyriform and flattened from before backward, except when affected by unsymmetrical newgrowths like fibromyomata, cancer, etc. The fundus is on a level with the uterine ends of the Fallopian tubes in nulliparæ and about 1 cm. above in multiparæ. In the *infant* and the child before puberty it is relatively small in **size**, the cervix is larger than the body, and the intravaginal segment of the cervix is relatively large. In the uterus of a young adult *virgin* the length is about equally divided between the cervix and the body. In the *nulliparous* married woman the body becomes somewhat larger than the cervical portion, and the entire organ measures about 6.5 cm. ($2\frac{1}{2}$ in.) in length and 4 cm. ($1\frac{1}{2}$ in.) in greatest breadth. When completely involuted after childbirth the uterus is always somewhat larger (about one-fifth) than before conception, and the length of the body is twice that of the cervix. In *old age* the entire organ atrophies, and this process begins after functional activity ceases at the menopause.

The **weight** in nulliparæ is about one ounce (30 gm.), in multiparæ an ounce and a half, in old age it may be as little as one to two drams, while at full term it may vary between twenty-two and forty-six ounces. The weight is somewhat increased during menstruation. Increase of weight may be due to pregnancy, inflammation, newgrowths, etc., and is a cause of various malpositions.

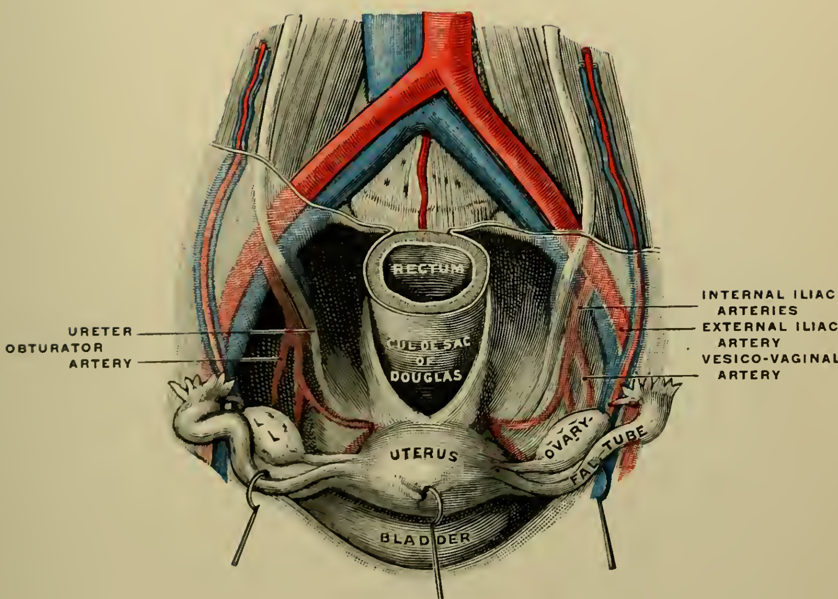
Position.—The uterus of the infant and *child* projects above the pelvic brim and lies almost wholly in the abdomen, compressed between the bladder and rectum and without flexion, as a rule. *Before puberty* it comes to lie entirely below the pelvic brim, but above a horizontal plane passing through the upper end of the symphysis, and remains so unless enlarged by pregnancy or by pathological processes.

The uterus, especially the body, is very *movable*, so that, if the cervix cannot be drawn down to the vaginal outlet, the condition is abnormal and the cause is to be sought for. On account of this mobility its **axis** is without doubt subject to considerable variation within normal limits. Normally the long axis of the uterus is directed forward (anteverted), in which position the intra-abdominal pressure is exerted upon the posterior surface of the body of the uterus, bending it forward on the cervix, so that it becomes anteflexed (according to Waldeyer, from 70 to 100 degrees). According to the last-named author the *external os* is on a *level* with the upper end of the symphysis, in a transverse vertical plane passing through the spines of the ischia, and the axis of the cervix is in line with that of the pelvis at this point. The condition of the neighboring intestinal coils may also affect its position. As the uterine axis forms an angle with that of the vagina, the lower end of the *cervix*, including the anterior and posterior lips and the external os, abuts against the posterior *vaginal wall*.

Fixation.—The broad or **lateral ligaments** fasten both the body and the cervix to the lateral walls and floor of the pelvis. The body is also supported by the **round ligaments** attached to its cornua and so directed as to hinder its posterior or lateral displacement and to some extent its downward prolapse. The other ligaments of the uterus, both true (uterosacral) and false (anterior and posterior), steady the cervix fore and aft. In addition the *cervix* is *fixed* by its attachment to the bladder and vagina so that it is the most fixed part of the uterus. As the origins and insertions of the round ligaments are approximately in the same horizontal plane, in the erect position, they offer little resistance to the descent or prolapse of the uterus, even when they are not relaxed, until it reaches a lower level in the first degree of prolapse, when they become really suspensory and oppose further descent. Prolapse is prevented principally by the support afforded by atmospheric pressure acting on the intact floor of the pelvis. The integrity of this floor, especially of the levator ani, by securing a tightly closed vaginal outlet, is the most important factor in the support of the uterus. If the vagina becomes an open, air-containing tube from relaxation of its outlet, due to perineal laceration, the support of atmospheric pressure on the pelvic floor is lost, as air is admitted above it. When the uterus becomes enlarged from

PLATE XLI

FIG. 148



The Female Pelvis and Pelvic Viscera from Above, the Uterus and Adnexa being Drawn Forward. (Testut.)

pregnancy or otherwise the ligaments stretch or lengthen to accommodate themselves to the new conditions. During involution of the uterus after childbirth the ligaments again contract and shorten, but if the uterus remains large and heavy (subinvoluted), or the patient gets up too soon, and especially if she strains herself by work before the balance between the uterus and its ligament is reëstablished, there is danger of uterine displacement, as it is not properly supported.

Displacements.—As we have seen the *cervix* is the *most fixed* part of the uterus, while the ligaments holding the body allow it more freedom of motion. The slightly constricted part (*isthmus*), where the more fixed cervix joins the heavier and more movable body, is an exposed and *weak point* where ante- and retroflexions occur, the body of the uterus bending on the cervix. In **anteflexion** the body is bent forward onto the bladder, and we can palpate it by combined vaginal and abdominal palpation, while in **retroflexion** the body occupies Douglas' pouch and presses upon the rectum, through which or the vagina it may be readily palpated. A certain degree of anteflexion is not pathological, but normal; pathological anteflexion usually causes dysmenorrhea, on account of the sharp bend in the canal.

If the uterus is anteverted or retroverted it seesaws on the *isthmus* as a transverse *axis,* so that if the body moves in one direction the cervix tilts in the opposite direction. Thus in **anteversion** the body lies upon the bladder, while the vaginal portion of the cervix tilts up and back into the posterior vaginal fornix; in **retroversion** the cervix, tilted forward, presses against the bladder, while the body of the uterus presses against the rectum. In either of these cases it may be difficult to make the external os present at the end of a speculum.

Any of these malpositions may tend to *prevent conception,* by reason of the position of the os or the obstruction due to the sharply bent canal. Anteversion is said to be more common among childless women, retroversion among women who have borne children, especially if after labor they have been bandaged too tightly and too long in the supine position. The retrodisplaced uterus also drags back the appendages.

As the *round ligaments* prevent backward displacement of the uterus, their *relaxation* allows of retroversion, and their *shortening* produces anteversion, which may also be caused by the retraction of the *utero-sacral* ligaments, by pulling the cervix backward and thus tilting the body forward. In anteversion or anteflexion the body of the uterus may so press upon the *bladder* as to cause some *irritability.* In retroversion the cervix presses upon the bladder near its outlet so as to cause more irritability of the bladder than the pressure of the anteflexed or anteverted uterus upon its less sensitive upper part. In the same manner the body in retroversion or retroflexion and the cervix in anteversion may so press upon the *rectum* as to cause rectal *tenesmus* and difficult and painful defecation, and thereby induce *constipation.*

The uterus displaced in any of the above ways may regain its normal position unless adhesions occur and fasten it to the viscus, against which it presses, whereby the symptoms due to pressure become chronic.

Either form of flexion may cause *dysmenorrhea* by obstructing the escape of the menstrual flow. When the supporting ligaments are relaxed and this condition is combined with a weakening of the support of the perineum, following its rupture, and an abnormally heavy uterus, the latter may sink or become *prolapsed* so as to present at the vulva or even to lie partly or wholly outside the vulva. The first degree of prolapse must be associated with some posterior displacement, so that the uterine axis may become parallel to the vaginal. Therefore the normal intra-abdominal pressure which helps to maintain normal anteflexion tends to prevent prolapse. A much rarer condition, and one more difficult to treat, is where the uterus is *inverted* or turned inside out. This may be due to the traction of a polypoid submucous fibroid. The normal uterus is so mobile that the cervix may readily be drawn down by a tenaculum to the vaginal orifice in operations which concern the cervix. In fact, if the uterus is found not readily movable, some pathological cause should be sought for. Lateral version, usually of the fundus to the left and of the cervix to the right (Merkel, Waldeyer) is very common and not pathological unless excessive or fixed.

Relations.—As the **rectum** lies behind it, we can examine the uterus, to determine its size and position, by palpation through the rectum almost if not quite as well as through the vagina, especially if there is retroflexion or retroversion.

Between the uterine body, the supravaginal portion of the cervix, and the upper 2 to 2.5 cm. ($\frac{3}{4}$ to 1 in.) of the posterior vaginal wall in front and the rectum behind lies the recto-uterine pouch of peritoneum, or the **pouch of Douglas.** The latter is strictly the lower part of the pouch, which lies below the laterally placed crescentic folds of the posterior false ligaments of the uterus, enclosing the uterosacral ligaments. Douglas' pouch normally contains the rectum, coils of small intestine, and part of the sigmoid loop. It is readily examined by the finger per rectum or per vaginam, or opened into through the posterior vaginal fornix, or drained through such an opening if occupied by an abscess. The peritoneum is reflected from the front of the isthmus onto the *bladder* to form the shallower **uterovesical pouch.** This contains the uterine body in its anteflexed position and perhaps some coils of intestine. The **subperitoneal connective tissue** continues down below this reflection of peritoneum and separates the cervix from the bladder, allowing the separation of the two along this plane in hysterectomy. This layer is continuous with that found at the sides of the cervix, between the layers of the broad ligaments, and with a more scanty amount beneath the peritoneum covering the back of the supravaginal portion of the cervix. The *cervix* is thus seen to be *enclosed* in a layer of *loose connective tissue* of varying thickness, continuous with the subperitoneal tissue. This facilitates the amputation of the cervix without opening the peritoneal cavity (*i. e.*, extraperitoneal).

From the above we see the **relation of the uterus to the peritoneum,** which covers the anterior and posterior surfaces and the upper end of the body, and the supravaginal portion of the posterior part of the

cervix. It is reflected from the sides of the body and cervix to form the broad ligaments.

Newgrowths, like carcinoma of the uterus, may extend onto the rectum or bladder, and vice versa, and the *ureters*, on account of their close relations to the cervix, may become occluded by the extension of a carcinoma to the latter, and uremia result.

The Cervix.—Of the *three zones* (Fig. 154) into which the cylindrical cervix is divided, the lower or **intravaginal zone** projects into the upper part of the vagina at such an angle that its lower end abuts against the posterior vaginal wall. This lower end contains the **external os**, or lower opening of the uterine canal, bounded by a lower *anterior lip*, short and thick, and a *posterior lip*, which is longer than the anterior by reason of the greater height of the posterior vaginal fornix. The *orifice*, a transverse fissure about 6 mm. broad in the virgin, becomes irregular after childbirth owing to the notching of its lips, so that by palpation of the os we can say whether a woman has borne children. This intravaginal portion of the cervix can be *seen* through the speculum or *examined* by the finger in the vagina, and is more exposed to lesions of all sorts than other parts of the cervix, especially to "erosions" and cancerous ulcerations. The first part that we see or feel on examination is usually the anterior lip.

The *cervix* may become *hypertrophied* so as to be *elongated* and project downward into the vagina unusually far. This may resemble a prolapse, but if we try to push it up, usually an easy matter in prolapse, resistance and pain are at once met with from the tension of its connections. This **elongation** may affect either the intravaginal or supravaginal portion of the cervix. In the former case the vaginal fornices are deepened, in the latter they are not. Such a cervix may even interfere with coitus, and a conical, pointed cervix is unfavorable to *conception* and may be a cause of *sterility*. Another cause of sterility as well as of dysmenorrhea is furnished by an *atresia* or narrowing of the os externum, by no means rare. The cervix may be enormously *enlarged* from chronic disease. During *pregnancy* it becomes broad and soft and is drawn up from the cavity of the vagina, the external os being occluded by a plug of mucus. The intravaginal portion, relatively large and prominent in female children, may nearly completely disappear in *old women*, and sometimes in younger multiparæ. It possesses so *little sensation* that we can insert a tenaculum to pull it down and make all manner of applications to it without producing much if any pain.

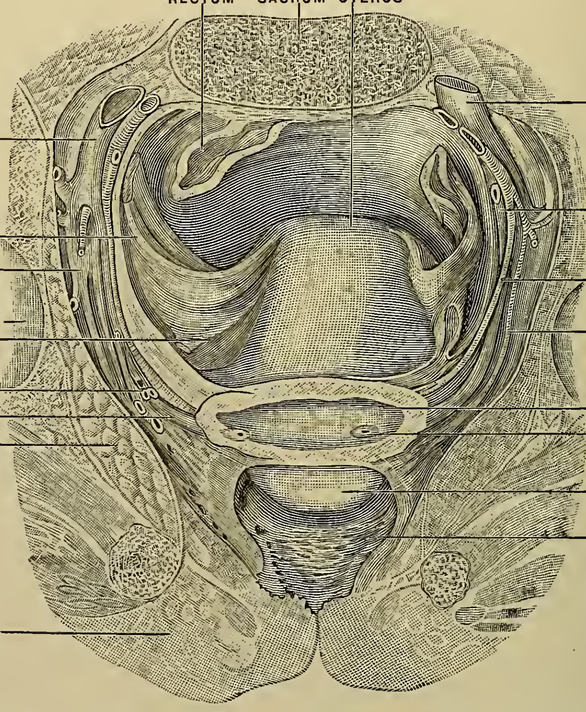
The **zone of vaginal attachment**, about 5 mm. deep, is obliquely placed, extending higher behind than in front, thus making the posterior lip longer and the posterior vaginal fornix deeper.

The **supravaginal zone** represents about half of the cervix behind and two-thirds in front. It is connected, as we have seen above, with the *bladder* anteriorly, while posteriorly it is covered by peritoneum and enters into the anterior wall of *Douglas' pouch*. Perhaps the most important relations of the cervix are found at its sides which are con-

nected with the *broad ligaments,* in which at this level lie the uterine vessels and the ureter. The *uterine artery* passes nearly horizontally inward in the base of the broad ligament to the supravaginal portion of the cervix, accompanied by the large uterine veins, arranged in a plexiform manner.

One of the most **important topographical points** in the female pelvis is the **crossing of the uterine artery in front of the ureter.** This occurs on a level with the intravaginal portion of the cervix and about 12 to 18 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) *from the cervix.* The ureter passes *through the plexus* of the uterine veins. The fact of the crossing is important, for it occurs

Fig. 149



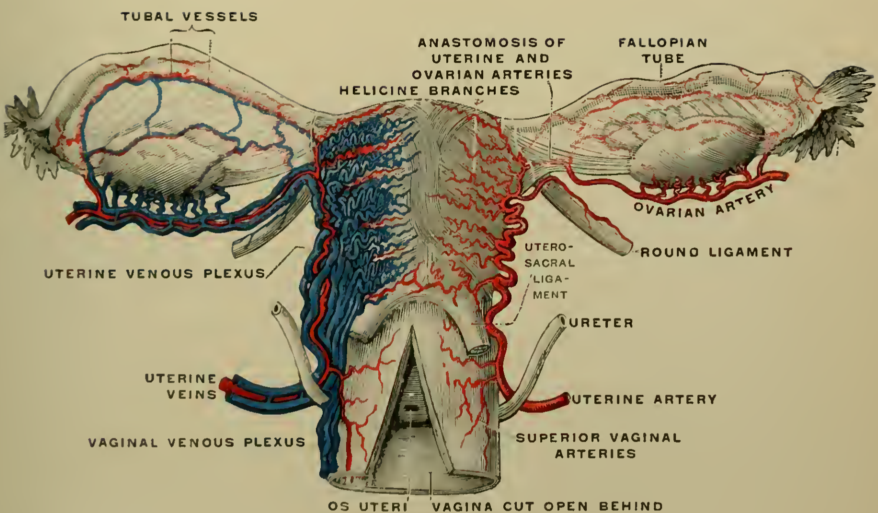
Frontal section of female pelvis, showing relations of ureter to uterus and its vessels.

close to where we tie or clamp the uterine vessels in removing the uterus or cervix. Hence there is danger of *wounding the ureter,* a danger which is real, for it has occurred in many reported cases. After crossing behind the uterine arteries the two *ureters,* converging slightly, incline somewhat forward so as to reach the front of the sides and then the anterior wall of the vagina.

The small **cavity** of the uterus is a mere fissure. The cavity of the body is triangular in shape, with an opening at each angle into the Fallopian tubes above and the narrow **internal os** below. The latter opening is at the upper end of the fusiform cervical canal, which ends

PLATE XLII

FIG. 150



Vessels of the Uterus and its Appendages, rear view. (Testut.)

below in a transverse fissure, the external os. The narrowness of the os internum may be such as to be an obstacle to the menstrual flow and a cause of dysmenorrhea. In old age it becomes still more contracted and even closed. The **cervical canal** may be gradually yet fairly quickly dilated so as to allow inspection and digital examination of the uterus and even the enucleation of large tumors. The *mucous membrane* of the cervical canal secretes a viscid alkaline mucus, and pathologically its mucous glands are liable to become vesicular, when they are sometimes known as ovula Nabothi. The motion of the cilia of the uterine mucosa is downward toward the os externum. The length of the uterine cavity averages about 5 cm. (2 in.) in nulliparæ and 5.5 to 7 cm. ($2\frac{1}{4}$ to $2\frac{3}{4}$ in.) in multiparæ. We can determine the length by the uterine sound.

As there is, strictly speaking, no cavity, the bulk of the uterus is made up of its **thick wall.** Apart from its remarkably thick *mucous membrane,* which is thickened and then partly cast off at the monthly periods and becomes the decidua during gestation, this thick wall consists principally of unstriped *muscle fibers.* This tissue, arranged in three imperfect layers, is remarkable for its hypertrophy and newgrowth during pregnancy, and it is largely by its contraction that the fetus is expelled. The muscle tissue of the uterus is continuous with that of the uterosacral, round, uteroövarian, and broad ligaments, and that of the Fallopian tubes, vagina, and bladder.

In this tissue in any part of the uterus, but more often in the body, develop the common **fibroids**, myomata or fibromyomata, as they are variously called. These may be single or more often multiple, and may attain a very large size; one of one hundred and forty pounds has been recorded, but, as a rule, they do not attain the size of the largest ovarian tumors. In their evolution they often acquire a partial or a complete *capsule* and may protrude on the surface (*subperitoneal variety*), or into the cavity (*submucous variety*), or they may remain within the walls (*interstitial variety*). They occur during menstrual activity, they tend to atrophy or degenerate after the menopause, and sometimes become involuted with the rest of the uterus after parturition. They are particularly common among negroes. The submucous variety is apt to cause severe *bleeding,* and hence should be removed early. The subserous variety is liable to adhesions from local peritonitis. They may prevent conception, cause miscarriage, or complicate parturition, according to their size and situation.

The uterus, enlarged from pregnancy or other cause, may press upon the iliac veins, causing hemorrhoids or varicose veins of the legs; on the lumbar or sacral nerves, causing neuralgia and cramps; or on the renal veins or kidneys, causing albuminuria, etc.

Owing to its small size, its great mobility, and the protection afforded by the pelvis, the unimpregnated uterus is rarely *wounded.* The *pregnant* uterus may be *ruptured* by violence or by its own contraction during labor, especially if the passage of the fetus is obstructed. The rupture is usually near the junction of the cervix with the body.

Vessels.—The uterus is supplied by the *uterine arteries* from the internal iliac and the *ovarian* from the abdominal aorta. The *uterine artery* of either side, passing nearly horizontally inward in the base of the broad ligament, *crosses in front of the ureter* (see p. 436) and reaches the side of the supravaginal portion of the cervix, whence it runs up along the side of the uterus, between the folds of the broad ligament. At the cornu or angle it *anastomoses* freely with the ovarian artery. In young individuals the artery lies 0.5 to 1 cm. ($\frac{1}{5}$ to $\frac{2}{5}$ in.) from the uterus and still further removed from the cervix and the lower part of the body. After repeated pregnancies it comes to lie nearer the uterus and becomes more tortuous, so that in operations it is more difficult to separate the artery from the uterus.

At the uterine end of the round ligament the small *funicular artery*, accompanying the round ligament, anastomoses with the uterine and ovarian arteries. Numerous transverse branches from the uterine arteries supply the uterus and anastomose across the median line. Owing to this fact and the free anastomosis with the ovarian artery, a ligature may be placed around the uterus without affecting the circulation above or below.

By a lateral *incision* into the upper end of the *vagina*, opening into the base of the broad ligaments, the *uterine arteries* may be pulled down and *tied*, the relation of the artery to the ureter being carefully borne in mind, as it should be also in securing and dividing the artery in hysterectomy. The **veins** form *large plexuses* and accompany the corresponding arteries.

Lymphatics.—The lymphatic plexuses of the cervix and body are continuous. The collecting trunks from the cervix enter the external and internal iliac and the lateral sacral nodes and those below the bifurcation of the aorta. Those from the body accompany the ovarian vessels and enter the lumbar nodes along the aorta.

Development.—The uterus and vagina are formed by the fusion of the lower ends of the two *ducts of Müller*, the two ununited upper ends of which form the Fallopian tubes. The *bicorned* and *double uteri* are due to the failures of this fusion in whole or in part, and they may be associated with a partial or complete septum dividing the vagina. Pregnancy as well as many of the pathological conditions may be confined to one-half or one cornu of a malformed uterus.

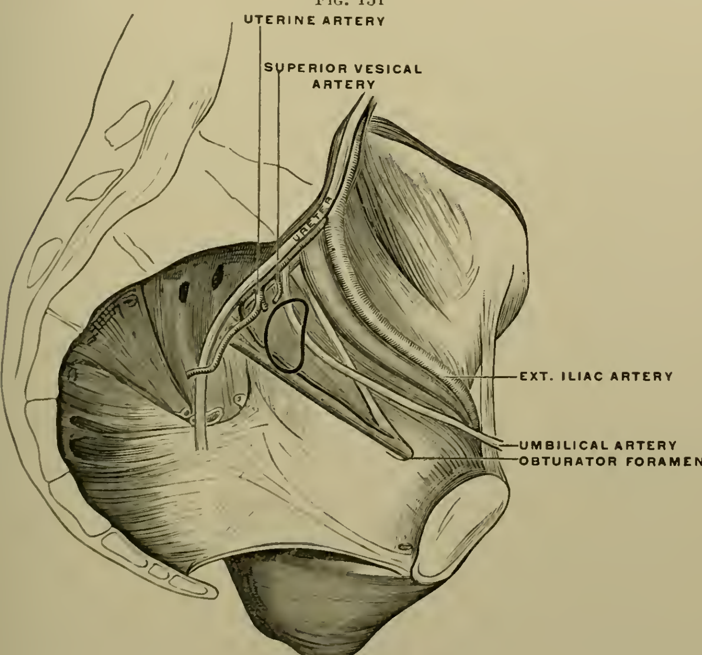
The *uterus* is *reached for operation* through a median celiotomy or through the vagina. In its removal (*hysterectomy*) *its connections* with the broad ligaments, vagina, and bladder are the principal things to be *divided* or separated. Remember that its *two arteries reach it through the broad ligament*, the ovarian at its cornu, the uterine opposite the cervix. We repeat again that the relation of the ureters to the cervix and the uterine vessels must be borne in mind.

The Ovary.—The ovary is a paired organ, *shaped* like a broad almond, whose *length* averages 3.7 cm. ($1\frac{1}{2}$ in.), *breadth* 18 mm. ($\frac{3}{4}$ in.), *thickness* 12 mm. ($\frac{1}{2}$ in.). Its *weight* is about 7 gm. ($\frac{1}{4}$ oz.) in the adult, the right being usually a little the larger. Before puberty it is small, it enlarges about puberty, and after the menopause atrophies very much.

Position.—We may describe a *typical position* of the ovary, remembering that, being a *movable body*, it may temporarily occupy other positions without causing any disturbance. The latter positions may more readily change into *abnormal positions* which do cause functional disturbances.

When the other pelvic organs are normal and there have not been repeated pregnancies, the **typical position** of the ovary in the upright posture is with its *long axis* vertical, its *attached border* in front and slightly external, its *free border* behind and slightly internal, toward the rectum, its *lateral surface* against the lateral pelvic wall in the fossa ovarica, and its *mesial surface* looking into the pelvis.

Fig. 151



"Fossa ovarica."

The **fossa ovarica**, or the depression on the inner surface of the internal obturator muscle in which the ovary lies, varies much in depth, and is *bounded* above and in front by the superior vesical artery, behind by the ureter and uterine artery, below and in front by the lateral attachment of the broad ligament. Lodged in this fossa the *lateral surface* of the ovary is not visible, and the attached border, upper end, and a variable amount of the free border and mesial surface are covered by the Fallopian tube, so that *but little* of the ovary *may be visible* on inspecting the pelvis.

The two ovaries are *seldom entirely symmetrical* in position, one being higher or more anterior than the other, and, if the uterus is deflected

to one side (according to His, to the left side in the proportion of three to two), the ovary on the opposite side is more exposed by the tube being somewhat drawn away from it, and its somewhat pointed lower pole may be drawn mesially. In the supine position the ovary lies with its long axis horizontal. The changing relations of the contiguous viscera also probably affect its position.

The ovary may be *displaced* into Douglas' sac or even into the utero-vesical pouch. Prolapse of the ovary is favored by its increased weight and the relaxation of its ligaments in subinvolution. The left ovary is prolapsed more frequently, for the arrangement of its veins favors venous congestion, analogous to left-sided varicocele in the male (p. 474), and it is said to enlarge more during pregnancy. It may be found, especially in childhood, in an inguinal or femoral *hernia*, where it is liable to strangulation, and it may become fixed in its abnormal position by adhesions. *In pregnancy* the position of the ovary is normally altered. *When enlarged* the ovaries may be *felt* through the vagina, or even better through the rectum. Their *position* is indicated *on the surface* by a point about 5 cm. (2 in.) internal to the anterior superior iliac spine and in a *sagittal plane* midway between the latter spine and the symphysis. A *frontal plane* at the promontory of the sacrum touches or lies just behind the ovaries. The position of the ovary corresponds to the middle of the upper margin of the acetabulum. In seeking for them when the abdomen is opened, the hand is passed along the back of the broad ligament from the uterus outward.

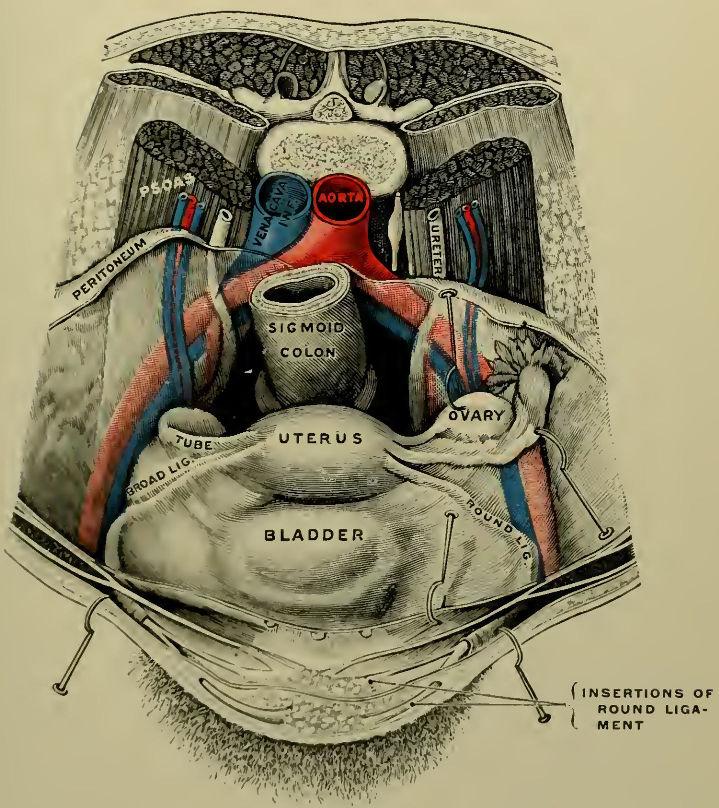
The ovary is supported and *held somewhat loosely in position* by the attachment of the tuboövarian ligament (fimbria ovarica) to its upper end and of the uteroövarian ligament to its lower end; by its mesovarium, a short fold covered on both sides by peritoneum from the posterior layer of the broad ligament, from which it projects backward; and by the **ligamentum infundibulopelvicum**, a fibromuscular band, containing the ovarian vessels, which is invested by a fold of the broad ligament and which *passes* from the side of the pelvis, above and in front of the ovary, to the upper end of its attached border where the vessels enter the hilum, between the layers of the mesovarium. This "ligament" forms part of the *pedicle* in the removal of the ovary or ovarian tumors.

We have named the most important **relations** of the ovary. The ureter, with the uterine artery in front of it, lies behind the ovary. External to the ovary, in the fossa ovarica, are the obturator vessels and nerve. Internal to the ovary, in addition to the Fallopian tube, are coils of intestine.

Structure.—The ovary receives from the posterior layer of the broad ligament an external covering, which differs from the serous membrane of the latter in being covered by *columnar epithelium*. Many of the ovarian *cysts* take origin in this epithelium. The surface is smooth before puberty and more and more scarred during menstrual activity. The *scars* represent where ovisacs have ruptured, and the larger ones in multiparæ the position of a true corpus luteum which forms when

PLATE XLIII

FIG. 152



Female Pelvic Viscera from Above. (Gerrish, after Testut.)

The ovary and tube of the left side have been lifted out of place.

pregnancy occurs. Slight extravasation of blood follows the rupture of an ovisac (or Graafian follicle), but when a vessel of unusual size is ruptured, or possibly when the ovary is unduly congested, a sudden copious bleeding may occur and the blood collect in Douglas' pouch as a *pelvic hematocele,* which we can then feel as a doughy tumor by vaginal or rectal examination.

The so-called **tunica albuginea** is a thin layer, and is merely a condensation of the ovarian stroma. Within it lies the cortex, containing numberless *Graafian follicles* (ovisacs) in various stages of development and the remains of some that have burst at the menstrual periods. Some ovarian tumors (cystic) are due to a collection of fluid in a dilated Graafian follicle (unilocular) or follicles (multilocular). The ovisacs, as they ripen, enlarge and approach the surface, where they appear as rounded projections when ready to rupture and set free the ovum.

The ovary may also be affected by *malignant newgrowths* and by *dermoid cysts,* the latter due to an island of epiblast abnormally included in the mesoblastic ovarian tissue. **Ovarian cysts or tumors,** if one side alone is involved, are at first unilateral in position, displacing the body of the uterus to the opposite side, the cervix usually to the same side. Later they ascend into the abdomen, drawing the adnexa attached to their pedicles upward with them, and displacing the intestine upward so as to cause dulness on percussion over them, in distinction to the tympanitic note we obtain in ascites from the bowel floating above or in front of the fluid. Strangulation from the twisting of the pedicles of ovarian cysts is not uncommon, especially if the pedicle is long and the cyst not adherent.

Development.—The ovary, developed in the lumbar region like the testis, is *pulled down* into the pelvis in a similar manner by the *inguinal ligament* of the primitive kidney. This ligament, attached to the uterus and the inguinal region, *remains* as the *uteroövarian ligament* between the ovary and the uterus, and the *round ligament* between the uterus and the inguinal region. In *hernia* of the ovary the fibromuscular uteroövarian ligament draws the uterus forward and to the side of the hernia, a fact that may be useful in diagnosis.

The upper series of Wolffian tubules may persist as a small pedunculated cystic sac, the *hydatid of Morgagni* (appendix vesiculosa), attached to the part of the broad ligament forming the free border of the mesosalpinx and adherent to the fimbria ovarica or one of the other fimbriae of the tube. The *parovarium* (organ of Rosenmüller) is the atrophied remains of the middle series of the Wolffian tubules, which in the male form the epididymis. This *lies* above the ovary in the mesosalpinx, and consists of several vertical tubes joining at right angles a horizontal tube, a segment of the Wolffian duct, which lies above them. The Wolffian duct disappears elsewhere, as a rule, but may occasionally persist as a small canal in the broad ligament close to the uterus, the *duct of Gärtner,* which is lost in the vaginal wall or may open near the urinary meatus. In these fetal structures, especially the parovarium, develop the majority of the unilocular cysts of the

broad ligament (*parovarian cysts*). These generally contain a clear fluid.

The Fallopian Tubes (*Oviducts*).—These *trumpet-shaped* tubes, about 11.5 cm. (4½ in.) *long*, are structurally continuous with the uterus at its superior angles, from which they pass outward to the sides of the pelvis, where they are closely related and connected with the ovaries. They *lie* between the two layers of the broad ligaments, along their upper free margins, so that the serous membrane covers three-fourths of their circumference and, being reflected off inferiorly, forms the *mesosalpinx*. The lower fourth of their circumference is in contact with the subperitoneal tissue between the layers of the broad ligaments. Thus a *tubal pregnancy* or a fluid collection in the tube (*hydrosalpinx or pyosalpinx*) when it *ruptures* may burst into the peritoneal cavity, a dangerous course, or between the layers of the broad ligament. At their uterine ends the tubes lie between and slightly above the round ligament in front and the uteroövarian ligament behind.

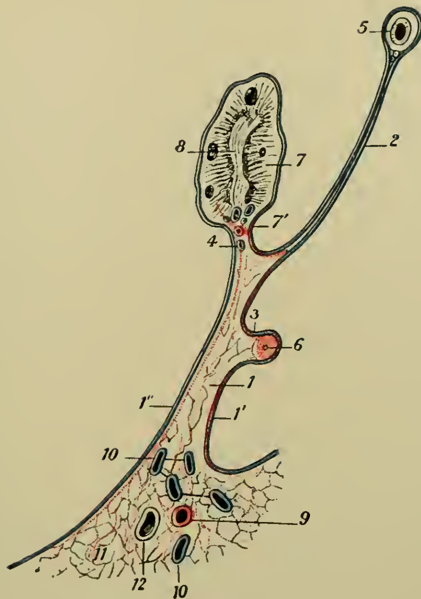
Course and Size.—At the outset it must be remembered that the tube, lying in the free margin of the broad ligament and connected with two movable viscera, the uterus and ovary, must, of itself, be *freely movable* to correspond to the changes in position of the uterus and other neighboring viscera. The *narrow, straight* inner portion, or **isthmus**, 3 to 6 cm. (1¼ to 2½ in.) long, passes nearly *horizontally* outward and slightly backward from each superior angle of the uterus to the uterine or lower end of the ovary at the side of the pelvis. Thence the *curved and dilated* portion, or **ampulla**, 7 to 9 cm. (2¾ to 3½ in.) long, bends sharply upward along the mesial aspect of the attached margin of the ovary to its upper or tubal end, over which it bends backward and then downward along the free border and the mesial surface, upon which rests the *funnel-shaped* **fimbriated extremity**, fringed by a circle or circles of *diverging fimbriæ* 1 to 1.5 cm. ($\frac{2}{5}$ to $\frac{3}{5}$ in.) long. Thus the ovary is more or less hidden (see Ovary, p. 439). One fimbria longer than the rest, 2.5 to 3.5 cm. (1 to 1½ in.), and attached to the upper end of the ovary (*fimbria ovarica*), constitutes the tuboövarian ligament.

The Fallopian tube forms a *passageway* between the *uterine cavity* (and thus the surface of the body) and the *peritoneal cavity*, whereby the ovum, when it escapes into the latter by the rupture of the ovisac, may reach the uterus. Hence also through this passageway uterine or vaginal douches and microörganisms may reach the peritoneal cavity and cause pelvic and perhaps general peritonitis.

The *fimbriæ* of the funnel-shaped outer end of the ampulla of the tube normally so embrace the ovary that they conduct the ovum into the abdominal opening of the tube. When from inflammation these fimbriæ become adherent together, or to neighboring parts, and close the opening on both sides, the ova cannot escape out of the abdominal cavity, and *sterility* results. Again, in rare instances, when the adaptation of the fimbriæ is imperfect, an ovum, fecundated by spermatozoa which have passed through the tube, may drop back and develop in the peritoneal cavity as one form of extra-uterine pregnancy.

PLATE XLIV

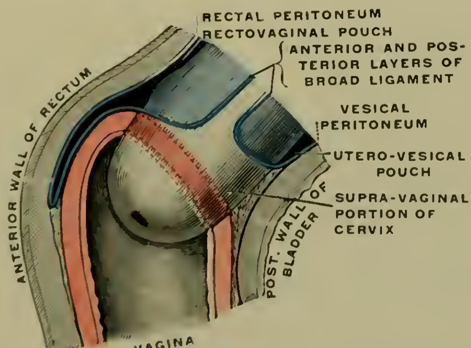
FIG. 153



Sagittal Section through the Ovary and Broad Ligament. (Testut.)

1. Broad ligament.
1′. Anterior surface.
1″. Posterior surface.
2. Mesosalpinx.
5. Fallopian tube.
6. Round ligament.
7. Ovary.
7′. Hilum of ovary with vessels entering the same.
8. Graafian follicle.
9. Uterine artery.
10. Uterine veins.
11. Cellular tissue at the base of the broad ligament.
12. Ureter.

FIG. 154



The Cervix Uteri and Upper End of the Vagina, showing their relations to the peritoneum. Diagrammatic. (Gerrish, after Testut.)

The **mucous membrane** which lines the tube is arranged in longitudinal folds and lined by a *ciliated epithelium* whose movement is toward the uterus, thus favoring the passage of the ovum. When from inflammation extending from the uterus, perhaps of gonorrheal origin, the tube has lost its epithelium, the descent of the ovum is hindered and the ascent of spermatozoa is not, thus favoring the occurrence of extra-uterine pregnancy. This is also favored by any cause which hinders the descent of the ovum through the tube. The great danger of ectopic gestation is the hemorrhage which follows rupture of the tube, some time before the fourth month. If the rupture is to be intraperitoneal, it usually occurs earlier than extraperitoneal rupture. The **lumen** of the tube varies, being about 1 mm. at the uterine aperture, 3 mm. in the isthmus, 8 mm. in the ampulla, and 2 to 3 mm. at the abdominal aperture. Ciliated epithelium extends along the inner surface of the fimbriæ and gradually merges into the endothelium of the peritoneum on their outer surface. The fimbriated extremities furnish the only instance where serous and mucous membranes adjoin one another.

As the *result of inflammation,* usually due to gonorrhea or sepsis following abortion, the tube may be *closed,* especially at its narrow points, the two extremities, first at the outer, later at the inner, so that the products of inflammation are pent up within the tube, which becomes *distended* to the size of the intestine (*hydro- or pyosalpinx,* pus tube). Such a pus tube may leak a little from time to time. If this leakage occurs into the peritoneal cavity recurrent attacks of pelvic peritonitis are produced. In chronic pus tubes, however, the pus is sterile in a large percentage of cases. The peritoneum on the surface of pus tubes is apt to contract adhesions to neighboring parts. The closure of the lumen of the tubes also causes *sterility.* The tubes are the most frequent seat of genital tuberculosis and the most frequent source of infection in peritoneal tuberculosis in the female. The proximity of the right tube to the appendix should be remembered, for it accounts for many mistakes in diagnosis, a right salpingitis being mistaken for appendicitis, and vice versa.

A *tube enlarged* by tubal pregnancy or from hydro- or pyosalpingitis may be *felt* by vaginal or rectal examination. They may be *reached for operation* (1) by the *vaginal route,* (*a*) laterally between the layers of the broad ligament, and therefore extraperitoneally, (*b*) posteriorly through Douglas' pouch, as in vaginal hysterectomy; (2) through an *abdominal incision.*

It should be remembered in operations that the fimbriated extremity may be in close relation with the ureter, a matter of importance if adhesions exist.

The tubal *blood supply* is from a branch of the *ovarian artery* running along its lower border in the broad ligament which forms its mesosalpinx.

In their *development* the Fallopian tubes represent the upper extremities or ununited parts of the ducts of Müller; hence morphologically as well as structurally they are continuous with the cornua of the uterus.

The Broad Ligaments.—These ligaments, also called **lateral ligaments**, from their position on either side of the uterus, form, as it were, a common *mesentery* for the uterus and its adnexa, especially the Fallopian tubes. They *consist* essentially of the *two layers of peritoneum* which, after covering the anterior and posterior surfaces of the uterus as described (p. 434), are reflected from the sides of the latter to the sides and floor of the pelvis, where they become *continuous* with the parietal peritoneum.

In addition to the Fallopian tube, ovary, round ligament, and fetal relics, the broad ligament of each side *contains* between its folds the uteroövarian ligament, the uterine, ovarian, and funicular vessels, the corresponding lymphatics, the uterine plexus of nerves, unstriped muscle tissue continuous with the uterus mesially, and *loose adipose cellular tissue* continuous with the subperitoneal tissue of the pelvis and sometimes called the parametrium. In this tissue, at the base of the ligament, lies the *ureter* in relation with the uterine vessels (see p. 436). *Inflammation* of this tissue (*parametritis,* if near the sides of the uterus) is the commonest form of *pelvic cellulitis* in women, is often puerperal in origin, and results in *abscess* in a minority of cases. Such an abscess may be opened through the lateral fornix of the vagina. The infection may *spread from* an inflammation of the small amount of similar tissue separating the muscular and peritoneal coats of the uterus (*perimetritis*), and it may extend to the similar tissue beneath the parietal peritoneum of the pelvis, or pass over the pelvic brim into the iliac fossa, where it often points just above Poupart's ligament (see p. 308).

The *muscular tissue* ensheaths the vessels and is of especial importance in serving as a *support* to the uterus and in helping to keep it in place. When the uterus enlarges during pregnancy it fills the space between the folds of the broad ligaments so that the latter nearly disappear, to reappear with the involution of the uterus. Hence for a time *after parturition* they are *lax* and offer but feeble resistance to uterine displacements, a reason for not allowing a woman to get up too soon after confinement.

Each broad ligament represents a *quadrilateral plate* which, with the uterus, divides the pelvis into an anterior (uterovesical) and a posterior (uterorectal) fossa. The **inner or mesial border** of the broad ligament represents its attachments to the sides of the uterus and the upper end of the vagina. In this border the uterine vessels pass up along the sides of the uterus. As the posterior fold passes onto the posterior surface of the upper end of the vagina we can understand how an incision in the lateral wall of this part of the vagina will open into the space between the two layers of the ligament at its base, and how we can palpate through the vagina any tumor or swelling situated here. The **base or lower border** of the broad ligaments rests upon the floor of the pelvis, formed by the levator ani and covered by the rectovesical fascia. The abundant areolar tissue here gives passage to the uterine vessels and nerves and the ureter, which pass from behind and external forward and inward. Here, as well as along its lateral border, its layers become

continuous with the parietal peritoneum of the pelvis. Owing to the slant of the pelvic cavity, the *anterior layer* is reflected at a higher level than the *posterior*, so that the latter is deeper or longer than the former. It is also more important on account of its direct relation with the ovary.

Its **lateral borders** transmit the ovarian vessels and the round ligaments and meet the sides of the pelvis, lined by the obturator internus muscle and fascia. The two layers are continuous along the **free upper border** of the broad ligament, which *contains* the Fallopian tube, so that the *upper part* of the ligament forms the *mesentery* of the tube (*mesosalpinx*). But the tube does not extend to the lateral limits of the broad ligament. The *outer part* of the free upper margin of the ligament, beyond the fimbriated extremity of the tube, is at a lower level than the mesial portion (mesosalpinx) and *contains* the *ovarian vessels* as they pass from the sides of the pelvis to the ovary, enclosed in a band of fibromuscular tissue, called the **infundibulopelvic ligament**, since it extends between the infundibulum (fimbriated extremity of the tube) and the side of the pelvis. Together with a portion of the broad ligament, the Fallopian tube, and the uteroövarian ligament it constitutes the *pedicle of an ovarian tumor*. Below the vessels is a thin, clear space through which a ligature may be passed and tied over the top of the ligament to control the ovarian vessels.

The upper part of the broad ligament which forms the *mesosalpinx* is *thin*, translucent, devoid of muscular tissue, and *contains* the fetal relics and the tuboövarian vessels. Projecting from and attached to the *posterior layer* is the ovary. More mesially the *recto-uterine or posterior ligaments* of the uterus are continuous with this same layer. *Between the folds* of the broad ligament are found unilocular *cystic tumors* (usually originating from fetal relics), hematocele, abscess, and tumors (intraligamentous), of which the cystic tumors are perhaps the most common. These may all be palpated through the vagina and reached for operation by means of a vaginal or abdominal incision. Unlike many ovarian tumors, they are commonly sessile and rarely, if ever, pedunculated. We are accustomed to think of the broad ligaments as vertical, and as such to describe them, but when we consider the normal anteflexed position of the uterus we find that the greater part, except the base, of the uterine end of the ligament is more horizontal than vertical.

The Round Ligaments.—These two rounded cords of unstriped muscle, fibrous and elastic tissue, about 12.5 cm. (5 in.) in *length*, commence at the upper lateral angles of the uterus just below and in front of the Fallopian tubes, where they are continuous with the superficial uterine fibers. Each *passes* at first outward and downward toward the base of the broad ligament; then nearly horizontally outward near the base of the ligament and beneath its anterior layer, in front of the ureter and the uterine vessels; thence upward, outward, and forward over the pelvic brim and the lower end of the iliac fossa to the internal abdominal ring. In the latter part of its course it *corresponds to* that of the *vas deferens*, and crosses, like the latter, the obturator and external iliac vessels and the unobliterated portion of the hypogastric artery

(*i. e.*, superior vesical artery). It finally loops around the outer side of the curve of the deep epigastric artery to enter the inguinal canal. In this part of its course also it not infrequently projects so far forward as to form a kind of short mesentery. In passing through the inguinal canal it receives a covering from the layers of the abdominal wall like the spermatic cord, but the striped fibers derived from the internal oblique (cremaster) are mostly attached to the pillars of the ring and the pubic spine. It may be accompanied by a process of peritoneum, the **canal of Nuck**, which corresponds to the processus vaginalis in the male and occurs as a sac-like pouch above and in front of the round ligament, not as a hollow tube around it, as is sometimes described. This serous pouch is *constant* in the fetus, occurs in children in 20 per cent. of cases (Zuckerkandl), and in isolated cases may persist even to adult life. But usually it is only represented by a funnel-shaped depression at the internal ring.

When present it *predisposes to inguinal hernia*, or if it becomes constricted the distal portion may form the sac of a "cyst of the canal of Nuck," analogous to an encysted hydrocele of the cord in the male.

After leaving the external ring, which in the female is smaller than in the male and lies just external to and a little above the pubic spine, the round ligament expands fan-like to be *attached* to the connective tissue of the labium majus and the periosteum over the pubic spine.

When the uterus is in its typical position, the round ligaments are not taut, but only when there is *backward displacement* or a *prolapse*, hence they play but a secondary role in supporting the uterus. Contraction or preternatural shortness of the ligaments is said to be a cause of anterior displacement of the uterus.

For downward or backward displacements *Alexander's operation* of shortening the ligaments, and thereby pulling the uterus forward and, if prolapsed, upward, has often been performed. The *incision* is like that for inguinal hernia.

Sometimes there is difficulty in *finding the ligament*, and for this purpose the external ring is exposed and the tissues below and internal to it are hooked up and pulled upon, or the canal is slit up for a distance and the contents of the canal similarly dealt with. We may pull down and *shorten the ligament* by as much as 10 cm. (4 in.) in some cases. After pulling down the cord for a certain distance a *pouch of peritoneum* is apt to appear at the external ring. This may represent the canal of Nuck, but almost always a new pouch pulled down from the peritoneum at the internal ring. Such a pouch occupying the canal naturally *predisposes to hernia* and the latter has not infrequently followed such operations, hence a Bassini operation should be performed in such cases.

The round ligament is *stronger* than one would suppose, and bears a very considerable traction (0.5 to 0.6 kgr., according to different observers). *In pregnancy* it becomes four times as stout as in the non-pregnant state.

Its **artery**, the *funicular*, is derived like that of the vas deferens from the superior vesical (*i. e.*, hypogastric), as the ligament crosses the latter.

It anastomoses with the uterine and ovarian at the uterine end and with the external pudic in the labium.

The Vagina.—This musculomembranous *passageway* between the vestibule and the uterus is *directed* upward and backward in the *line* of the pelvic outlet below and the pelvic axis above. It forms an angle of 25 to 35 degrees with the long axis of the body, of 65 to 75 degrees with the horizon, and of more than 90 degrees with the cervix, but these measurements vary with the pelvic inclination of the individual and with the condition of the bladder and rectum. Nearly half of it lies below the plane of the pelvic outlet.

Its *walls* are ordinarily in *contact,* and it presents on transverse section an H-shaped fissure. In the knee-chest position the walls are separated and the cavity distended by air, affording easy inspection. Its **anterior wall** *measures* 6.5 to 7.5 cm. (2½ to 3 in.) in length, the *posterior* nearly 8.5 cm. (3½ in.). In the *lateral dimensions* it is extraordinarily *dilatable,* being limited only by the pelvic wall so as to admit the passage of the fetus at birth. The **anterior wall** is in *close relation* with the *urethra* below and the *bladder* above. The *trigonum vesicæ* and the base of the bladder just above it are connected with the vaginal wall by areolar tissue, continuous with the subperitoneal tissue between the cervix and the bladder. So close is this connection, especially with the trigonum, that when the *vagina is everted* like a glove-finger *in prolapse* of the uterus the bladder wall is drawn down with it as a pouch projecting into the vagina (*cystocele*). In complete prolapse the *urethra,* the lower two-thirds of which is most *intimately connected with* the *vaginal wall,* is also inverted, so that from the meatus its direction is downward and backward. When the support afforded by the perineum is weakened by its rupture a cystocele may project into the vagina without uterine prolapse, but, according to Sims, a cystocele always precedes complete prolapse of the uterus.

Owing to prolonged pressure between the fetal head and the pubic bones during a tedious labor, the vesicovaginal septum may slough and give rise to a *vesicovaginal fistula.* Similar fistulæ may also occur from a like cause between the urethra and vagina or between the bladder and cervical canal, or these three forms of fistulæ may be combined in one.

The *trigonum vesicæ* is *faintly indicated* on the *anterior vaginal wall* as follows: the *base* by a transverse fold of mucous membrane, slightly convex inferiorly, about 2.5 to 3 cm. below the external os uteri, and the *sides* by two folds which diverge from the upper end of the anterior columna rugarum. Pawlik used these markings in *catheterizing the ureters,* whose openings are at the upper angles of the trigonum, but we have an easier and surer way in Kelly's method through a urethral speculum. Above the base of the trigonum the *ureters pass* upward and outward, diverging somewhat so as to reach the upper end of the lateral vaginal walls, where they occupy the triangular space between the levator ani muscle and the vagina. *Calculi* lodged in the lower 6 to 7.5 cm. (2½ to 3 in.) of the ureters may therefore be *felt and removed* through the upper part of the vagina.

The lateral walls of the vagina are in *contact* above with the *base of the broad ligaments* and their contents, including the uterine vessels. Hence we can here palpate or expose these parts by incision (see Broad Ligaments, p. 444). In its lower two-thirds the lateral vaginal wall is embraced by, but not attached to, the median portion of the levator ani muscles, which with the rectovesical fascia effectively support it. In the triangular space between these structures and the sides of the vagina is the vesicovaginal plexus of veins.

The **posterior vaginal wall** is in *contact* with the *rectum,* from which its upper fourth (2 cm. or so) is *separated by* the peritoneal **pouch of Douglas,** its middle portion by *areolar tissue,* continuous with the subperitoneal connective tissue, and its lower end by the *perineal body.* Hence we can *palpate* through the vagina the *contents* of the lower end of *Douglas' pouch,* whether this be the coils of intestine, normally present, or a retro-uterine hematocele, a retroflexed uterus, a uterine fibroid, a displaced and perhaps cystic ovary, or a pus tube. Through the upper end of the posterior vaginal wall we may *reach by incision* the *peritoneal cavity* in Douglas' pouch, and through this incision drain an abscess, break up adhesions behind the uterus, or reach and operate upon its adnexa. The peritoneal cavity may also be opened by traumatism inflicted through the vagina, and through such an opening intestinal coils may protrude. Rarely the intestinal coils occupying Douglas' pouch may protrude from above and behind into the vagina as an *enterocele,* or lower down the rectum may form a similar pouch, or *rectocele.* Such a pouch does not necessarily accompany a prolapse of the uterus with eversion of the vagina, for the latter is more *loosely connected with the rectum* than with the bladder, and may not pull it down. Similarly in prolapse of the rectum the vagina is not necessarily pulled down.

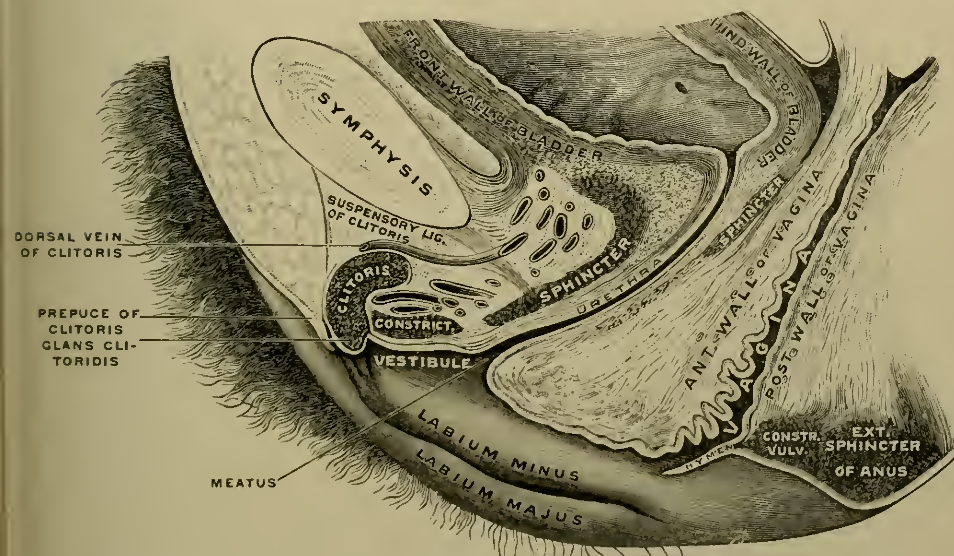
Although the **rectovaginal septum** does not suffer from pressure as does the vesicovaginal, yet it may be *torn* through even to a high level at childbirth. If such a complete rupture is not healed throughout, it may leave a *rectovaginal fistula.*

The **upper end** is the *largest part* of the vagina. Its angle of reflection onto the cervix is known as the **fornix,** and should be supple when normal. Into this upper end the intravaginal portion of the cervix projects at an angle. (See Uterus, p. 435.) The *line of vaginal attachment* is *oblique* from behind forward and downward, making the *posterior vaginal fornix* much *deeper* than the anterior, and the posterior vaginal wall longer than the anterior, so that it may occasionally be difficult to reach the limit of the posterior fornix with an examining finger of moderate length (7.5 cm.) without considerable pressure, or to explore the pouch of Douglas without general anesthesia, which greatly facilitates bimanual examination.

The **lower end** is the *narrowest* part, and may be still further *narrowed by* the engorgement of the *bulbs of the vestibule,* which flank it on either side, and by the contraction of the constrictor or *sphincter vaginæ* and perhaps also of the levatores ani. The spasmodic contraction of the constrictor vaginæ, known as **vaginismus,** may interfere with coitus.

It may require surgical treatment, but the surrounding parts should first be carefully inspected to discover if possible some cause of reflex irritation. As the vagina near its lower end *pierces* the *triangular ligament* and is intimately attached to it, this part of the canal is also the most resistant to dilatation. The lower end, *orificium* or *introitus vaginæ,* is partly shut off from the vestibule in the virgin by an *imperfect septum,* **the hymen.** This membranous fold varies much in *shape,* but it is usually crescentic and attached behind and laterally, having an opening in front, although it may form a complete septum, with one, two, or several small openings, or occasionally with no opening (*imperforate hymen*). The latter condition causes a damming back of the menstrual flow, which fails to appear, and, unless relieved, distends

FIG. 155



Sagittal section of the vagina and neighboring parts. (Gerrish, after Testut.)

the vagina, the uterine canal, and even the tubes, and hence calls for surgical relief. Although the hymen is usually *ruptured* by the first coitus, it may not be until parturition, hence it is not a proof of virginity, nor is its absence incompatible with virginity. After parturition remains of the hymen appear as rounded elevations (*carunculæ myrtiformes*) around the orificium vaginæ, the exact position of which they indicate. The transverse folds of the vagina render sterilization difficult by favoring the retention of discharges. Owing to the continuity of the vaginal and uterine mucosæ, infection of the former (vaginitis) readily spreads to the latter (endometritis).

As to **structure,** the very **elastic** mucosa, lined by stratified epithelium, is destitute of glands, hence vaginal discharge is of the nature of a transudation. Beneath the mucosa is a rich *venous plexus,* which

may be regarded as *erectile tissue* and may become *varicose* and form a pile-like tumor near the external orifice. The lymphatics of the lower third of the vagina pass to the supero-internal group of inguinal nodes; those of the upper two-thirds pass with those of the cervix uteri. In infancy and *childhood* the vagina is often relatively long, corresponding to the high position of the pelvic viscera; in *old age* it undergoes atrophy and sometimes partial closure. *Congenitally* it may be more or less completely divided by a vertical septum into lateral halves, usually connected with the halves of a bifid uterus. Such a septum may require division to allow parturition. It may also be very small and rudimentary, or even wanting. In the latter conditions other parts of the genital system, uterus and ovaries, are likely to be rudimentary or wanting.

The Female Urethra.—This *represents* that *portion* of the male urethra between the internal meatus and the openings of the ejaculatory ducts. It passes through the two layers of the rather indistinct triangular ligament and the striped muscular fibers representing the compressor urethræ muscle (deep transverse perinei). *Striped fibers* surround the urethra as a *sphincter* in its upper 1 cm. only, where it is connected to the vagina by loose connective tissue; in the lower part of the urethra, where the urethral and vaginal walls blend closely to form the urethro-vaginal septum (1 cm. thick above), these fibers occur in front only. *Circular unstriped fibers* together with fibers from the trigone surround the *vesical end* and form a powerful *sphincter*. As may be proved by distention of the bladder in the cadaver, no muscular action of the sphincters is necessary to retain urine, provided there is no vis a tergo through abdominal pressure or the contraction of the bladder.

The *urethra* may be *felt* between the anterior vaginal wall and the pubes like a *round cord*. The female urethra *measures* 3.5 cm. ($1\frac{3}{8}$ in.) in length. In the erect position it is *directed* downward and slightly forward, nearly parallel with the vagina, though inclining more forward below. Hence its lower end is farther from the vagina than the upper end. It is *slightly convex* backward, yet not enough to interfere in any way with the passage of a straight catheter. Its *exit from the bladder* is a little below and 2.5 cm. (1 in.) behind the middle of the symphysis. It *passes* 1.5 to 2 cm. ($\frac{3}{5}$ to $\frac{4}{5}$ in.) *below the subpubic arch*, and its **external meatus**, usually a *sagittal fissure* about 5 mm. in length, is found near the base of the vestibule on a papilla 2.5 cm. (1 in.) behind the clitoris, and 1.5 to 2 cm. below the subpubic arch. It is possible after practice to *pass a catheter* without exposure of the parts by means of the latter measurements, or better by means of a *tubercle* just behind the meatus at the lower end of the anterior columna rugarum of the vagina. This practice is to be condemned, however, as it is much more likely to carry infection to the bladder than when done aseptically with the aid of sight. In children and when the parts are swollen, as after a difficult labor, the meatus is relatively far back and difficult to find.

The *meatus* is the *narrowest part* of the canal, which averages 7 to 8 mm. in diameter, but it is extremely *dilatable*, as it is not surrounded by dense, resisting structures as in the male. Thus it may be *gradu-*

ally dilated under a local or general anesthetic so as to allow the removal of small calculi or foreign bodies, and the introduction of the finger for exploration or of the cystoscope for examination or ureteral catheterization. The resulting *paralysis*, if it occurs, quickly disappears unless the dilatation has been too great and too abrupt, when it may persist, as reports of cases show. In cases of imperforate hymen and narrowness or absence of the vagina the urethra has even become the channel of sexual intercourse.

In the *submucosa* is a *cavernous venous plexus* which gives the mucosa a darkish hue during life and may become *varicose* and form a pile-like tumor near the meatus. Small vascular tumors (papillary angiomata) may spring from the mucous membrane at or near the meatus, especially in its posterior segment. These "**urethral caruncles**" bleed readily, and are highly sensitive and sometimes very painful, so as to give rise to marked local and general symptoms and to demand removal.

Since the female urethra is a short, wide tube which serves the purpose of a urethra only, *inflammation* is less common, less severe, and easier to treat than in the male, and stricture is rare, less complete, and often requires no treatment.

EXTERNAL GENITALS.

A. THE FEMALE EXTERNAL GENITALS.

The Vulva.—The vulva is really a *cleft-like space* between the rima pudendi (the urogenital cleft between the two labia majora) inferiorly, and the hymen or its remains superiorly. It includes all the other external genitals in the female. The two **labia majora** *represent* the two lateral halves of the scrotum in the male, and, like it, are *composed* of *skin* enclosing an imperfectly developed *dartos*, and are subject to the same *pathological conditions*. They are the usual situation of elephantiasis in the female, are greatly swollen in cases of edema, and may contain large extravasations of blood (pudendal hematocele) after injury. They contain a considerable amount of fat, with whose fibrous capsule and partitions the round ligament is connected. *Inguinal herniæ* (sometimes containing the ovary) may descend into them anteriorly, *pudendal herniæ*, which escape between the vagina and the pubic ramus, more posteriorly. Cystic collections, probably in the unclosed canal of Nuck, and known as "*hydrocele in the female*," may also occur in the labia majora.

Posteriorly their ends taper and blend with the perineum, and are usually connected by a transverse fold, the *posterior commissure*, a little in front of the anus.

The Labia Minora or Nymphæ.—The labia minora or nymphæ *contain* much vascular tissue, and are not infrequently redundant, projecting below the vulva, especially in certain races (*i. e.*, Hottentots, etc.). On approaching the median line anteriorly they *bifurcate* and their

branches unite from side to side to form the *preputium* and the *frenulum* of the clitoris. Extravagant importance has been attached by some to the adhesion of this prepuce to the clitoris as a cause of various symptoms. In the young subject the posterior ends of the nymphæ are usually connected by a crescentic fold, the frenulum or *fourchette,* which is often torn in parturition and is the common seat of chancres in the female.

The **bulbi vestibuli,** two pyriform masses of erectile tissue corresponding to the lateral halves of the corpus spongiosum of the male, lie on either side of the orifice of the vagina and extend thence on either side of the vestibule, beneath its mucous membrane, to a point below the clitoris, where the two connect with one another and with the glans clitoridis. Rupture of the bulb may occur from injury, especially during pregnancy, when they are enlarged, and results in the formation of a large hematoma (*pudendal hematocele*).

Often overlapped by the bulbi vestibuli and on either side of the posterior third of the vaginal orifice lie the two **vulvovaginal glands** (*the glands of Bartholin*), which probably represent Cowper's glands in the male. The *ducts,* 18 mm. ($\frac{3}{4}$ in.) long, *open* just outside of the vaginal orifice and a little behind its centre, where the opening may often be seen as a small, red depression on everting the nymphæ and pressing the hymen inward. The *glands* are 8 to 12 mm. ($\frac{1}{3}$ to $\frac{1}{2}$ in.) long, *lie* beneath the superficial perineal fascia, and, like the bulbi vestibuli, are *covered* externally by the sphincter vaginæ (bulbocavernosus) muscle. The duct and gland are liable to *inflammation* and suppuration, often of gonorrheal origin. The resulting *vulvovaginal abscess* is felt in the base of one of the labia majora and cause edema there. Cystic dilatation of the duct is not infrequent. These glands atrophy after the menopause, if not before. In general, the vessels and nerves of the external genitals correspond to those of the homologous parts in the male; thus the lymphatics enter the inguinal nodes.

B. THE MALE URETHRA AND EXTERNAL GENITALS.

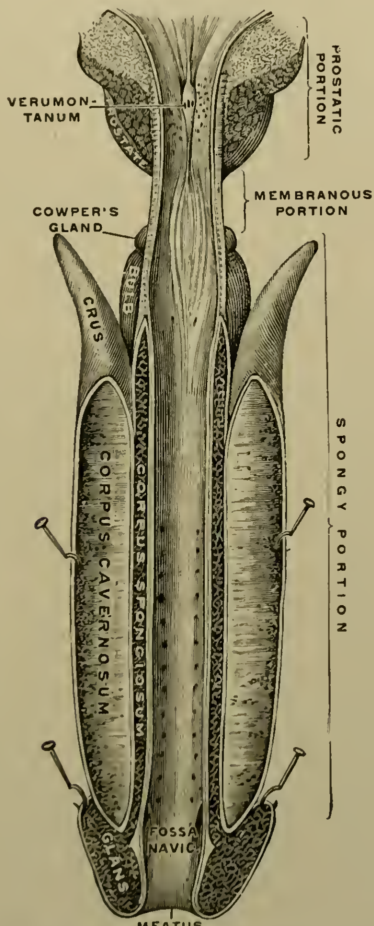
The Male Urethra.—The urethra is to be regarded as a *closed valve* whose walls are usually in contact. It is a *canal* only when open for the passage of urine, semen, or instruments.

Divisions.—In its passage from the bladder at the vesical outlet, or internal meatus, to the external meatus it is divided in various ways according to (1) the parts through which it passes (prostatic, membranous, spongy, etc.), (2) its fixity and mobility, (3) its direction (curved or straight), (4) its pathological and therapeutic peculiarities (anterior and posterior urethra).

The Prostatic Urethra.—The prostatic urethra, 2.5 to 3 cm. (1 to $1\frac{1}{4}$ in.) *long,* is spindle-*shaped.* Its upper narrowed end, the *vesical outlet* or internal meatus, is formed by the *annulus urethralis* (see p. 459). The latter is, as a rule, quite *dilatable,* but may become thickened or more resistant as the result of spasmodic action during micturition in gouty

subjects or in those with chronic urethral trouble. In such cases the condition may be relieved by stretching, with or without a slight incision. If in such cases the prostatic sinus is deep, the beak of the catheter or sound may impinge on its posterior wall, under the back of the annulus, and thus enter the bladder with difficulty if at all.

FIG. 156



The male urethra laid open on its anterior (upper) surface. (Gerrish, after Testut.)

The central, dilated part of the prostatic urethra presents an *inverted U on cross-section*, owing to the median projection from behind of the **verumontanum.** This contains *erectile tissue*, and may serve to close the upper end of the urethra and prevent the passage of semen back into the bladder. On its summit in the median line is the fair-sized opening of the sinus pocularis, or *uterus masculinus*, the homologue of the uterus. This blind sinus *runs* upward and backward for 6 to 12 mm. ($\frac{1}{4}$ to $\frac{1}{2}$ in.) beneath the "middle lobe." On either side of it run the *ejaculatory*

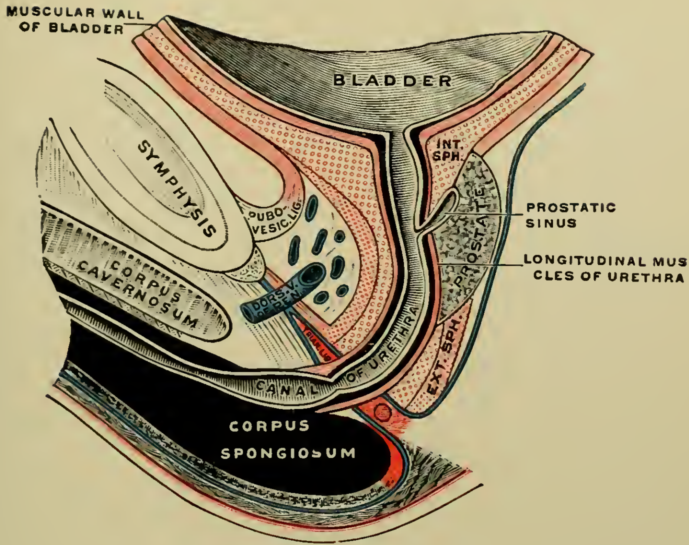
ducts, whose slit-like openings are on either side of (sometimes within) that of the sinus. In the two depressions or **prostatic sinuses,** one on either side of the verumontanum, open the *ducts of the glands of the prostate,* of which two are larger and more noticeable than the others. The tip of a sound may lodge in the prostatic sinuses, especially in cases of prostatic enlargement. To avoid this the beak of a "prostatic catheter" is longer and curved farther forward and the flexible catheters are made with the tip bent up (Mercier's coudé catheter). The tip of a small sound or bougie may also lodge in the sinus pocularis unless it is made to hug the upper wall. On account of the various openings into the prostatic urethra we can understand how an *inflammation* of this part *may extend* (1) into the bladder and thence to the ureters and kidneys, (2) into the ejaculatory ducts and thence to the seminal vesicles or along the vas deferens to the epididymis, etc., or (3) into the substance of the prostate.

In the erect position the *course of the prostatic urethra* is *nearly vertical,* with a slight concavity forward. It runs in front of the middle of the upper two-thirds and about the middle of the lower one-third of the gland, although cases have been observed when it has merely occupied a groove on its anterior surface. The prostatic portion is not only of *large caliber,* but also *very dilatable,* readily admitting the passage of the finger in operations on the urethra or bladder. Stricture is unknown in this part, although congenital folds and pockets may occur here and interfere with micturition. The lower half of the prostatic urethra may be *incised* in the median line without injuring other structures. Median incisions in the upper half must be in the exact median line to avoid the ejaculatory ducts.

The membranous portion, or that lying between the two layers of the triangular ligament, is *directed* obliquely downward and forward, and forms the beginning of the subpubic curve. It is, next to the external meatus, the narrowest segment and measures about 12 mm. ($\frac{1}{2}$ in.) in *length,* although the floor is said by some to measure less than the roof, owing to the projection backward of the bulb along the floor. It is *surrounded by* the *compressor urethræ muscle,* which forms the dividing line between the anterior and posterior portions of the urethra, and the cause of the so-called spasmodic strictures. Close *behind* it lies the bend in the anterior wall of the *rectum* between the anal and pelvic portions. At this point an instrument can be felt within or guided into the membranous urethra, or the false passage of an instrument may be felt by the finger in the rectum. Beneath and on either side lie the bulbo-urethral glands (*Cowper's glands*), the homologue of the glands of Bartholin in the female. Enclosed by the compressor urethræ muscle and resting on the upper surface of the superficial layer of the triangular ligament, 5 mm. ($\frac{1}{5}$ in.) apart, these glands thus lie above and behind the bulb. The formation of *cysts or abscess* may occur in them, the latter by extension of gonorrheal inflammation from the bulbous urethra, into the floor of which their *ducts,* 1.5 to 2.5 cm. ($\frac{2}{3}$ to 1 in.) long, open. They atrophy as age advances.

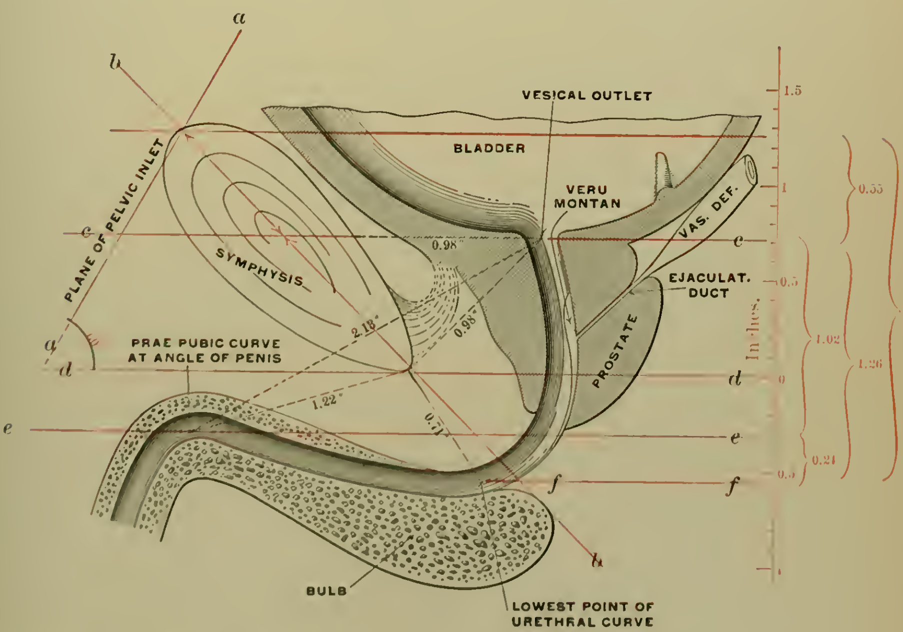
PLATE XLV

FIG. 157



Proximal Portions of Urethra, with surrounding parts. (Gerrish, after Testut.)

FIG. 158



Outline Diagram of the Curved Portion of the Urethra, showing the distances from and the relations of the different parts to the symphysis. (Testut.)

The spongy portion, 13.5 cm. ($5\frac{1}{2}$ in.) in *length*, includes several *subdivisions*. The **bulbous portion**, about 2.5 cm. in *length*, is the most posterior. Immediately in front of the triangular ligament the bulb at first covers only the floor and then gradually the sides, while the front of the urethra is not covered by spongy tissue until 0.5 to 1 cm. lower down, so that some authors call the portion not covered by the bulb the pre-diaphragmatic or *pre-trigonal portion.* The front wall of the latter portion is thinner than elsewhere. Along *the floor* of the bulbous portion the urethra is much *dilated*, and this dilatation (*fossa bulbi*) passes suddenly, not by a gradual narrowing, into the narrow and firmly fixed membranous portion at the point where the latter pierces the firm anterior layer of the triangular ligament. This is the *critical point in the passage of instruments*, for if the instrument is allowed to follow the floor it sinks into the dilatation of the bulb below the level of the opening into the membranous portion and then impinges on the triangular ligament, or if pressed *too* closely against the thin, dilatable anterior wall, a like result may happen. *To enter* the narrow opening of the *membranous urethra* ("neck of the bulb," as the French call it) the *sound* should be *kept along the roof* of the urethra, and as large an instrument as will pass should be used, for it is less likely to catch. We have seen that hugging the roof is also the rule in passing the prostatic portion to avoid catching in the sinuses and the annulus.

The bulbous portion continues the *subpubic curve*, commenced in the membranous portion, and *in the erect position* it forms the *most dependent part of the fixed portion* of the urethra. Hence the products of inflammation naturally gravitate here, and, as the parts are bathed in pus, chronic inflammation is apt to linger here and its results are seen in the *common occurrence of stricture.* The chronic inflammation, or *gleet*, alters the lining mucosa so that plastic material is deposited beneath it to prevent the soaking of urine into the surrounding tissues. The natural contraction of this plastic exudate narrows the lumen, and stricture results. This keeps up the irritation and the discharge, which is only cured by the cure of the stricture. The bulb is *covered* externally by the accelerator urinæ muscle (bulbocavernosus).

In front of the bulb the urethra continues in a fixed position, nearly horizontally, but with a slight upward inclination, to a point beneath the suspensory ligament. In front of this ligament the urethra is movable with the penis. The *caliber* of the spongy urethra is fairly uniform between the bulb and the *fossa navicularis*, the dilatation in the glans penis, especially along the urethral roof. At its distal end this fossa ends in the **external meatus**, a vertical slit on the antero-inferior aspect of the glans. The meatus is the *narrowest and least dilatable portion* of the urethra, so that any instrument which can pass the meatus should pass the rest of a normal urethra. To allow the use of large sounds or instruments in the treatment of pathological conditions of the rest of the urethra or the bladder (*i. e.*, litholapaxy, cystoscopy, etc.) the meatus must be *enlarged by slitting* it inferiorly in the middle of the frenum. The meatus may be *congenitally small*, even admitting only a fine

probe. This condition is often associated with congenital phimosis, and may occasion sufficient reflex nervous disturbances and urinary obstruction to require meatotomy. Besides the many mucous glands found in all parts of the urethra, especially in and near the navicular fossa, the small pits or *lacunæ of Morgagni* occur in the spongy portion in longitudinal rows, a median row of larger lacunæ on the anterior or upper wall and a row of smaller lacunæ on either side of it. As the *openings* of these lacunæ are *directed toward the meatus,* the larger ones may catch the tip of a small sound or bougie, thereby interfering with treatment or misleading the diagnosis. Hence instruments should be passed along the lower wall or floor of the spongy portion. An additional reason for this is found in the presence of a lacuna of large size, the *lacuna magna,* 1 to 2.5 cm. ($\frac{1}{2}$ to 1 in.) from the meatus, in the roof of the navicular fossa, which may easily arrest the point of an instrument. It is nearly covered below by a semilunar valve-like fold (the valvule of Guerin).

According to its fixity the urethra is divided into **a fixed and a movable part** (pars fixa and pars mobilis). These divisions do not correspond to the preceding, but more to the next following division, for the **fixed portion includes** the prostatic, the membranous, and the proximal 5 cm. (2 in.) of the spongy portion, or as far as the anterior border of the suspensory ligament. This is also known as the perineal urethra, the remainder as the penile urethra. The *membranous portion* is the *only absolutely fixed part,* and therefore of the greatest importance in catheterization, for we must direct the catheter to and through it; its position does not change to suit the catheter. The prostatic portion may be moved within the moderate limits allowed by the puboprostatic ligaments and the other connections of the prostate. The *bulbous portion* is the *most movable part of the fixed portion,* and lies immediately in front of the most fixed part. This is one reason for the difficulty of directing the point of the catheter or sound into the membranous portion, for the bulb may be easily pushed backward or sideways. The *rest of the spongy portion* of the urethra is the **pars mobilis,** and it depends for its position and direction upon that of the penis. For the introduction of instruments this portion may be put in the most suitable position for the purpose.

In **direction** the urethra is median, but may deviate somewhat laterally in micturition. It presents a *curve,* concave forward and upward, beneath the symphysis, the **subpubic curve**, and a **prepubic curve** where the fixed and movable portions join. The latter curve, with its concavity downward, is at the junction of the fixed and movable portions, and is present in the flaccid state of the penis, but is obliterated when the penis is erected or raised up. Hence in the passage of instruments we raise the penis and have to deal only with the *subpubic curve.* The latter curve is *most marked in* the membranous and bulbous portions, although it is continued slightly in the upward direction in the prostatic urethra, which is nearly vertical, and in the forward direction about to the prepubic curve, or the end of the fixed portion, though the anterior portion

of this rises but little, 5 to 6 mm. ($\frac{1}{5}$ to $\frac{1}{4}$ in.), above the level of the lowest point of the curve. The curve (Fig. 152) is described as being an *arc of a circle* having a *diameter* ranging, according to different authors, from 8 to 12 cm. ($3\frac{1}{4}$ to $4\frac{4}{5}$ in.), the chord of the arc measuring about 5.5 to 7 cm. ($2\frac{1}{5}$ to $2\frac{3}{4}$ in.). The curve is sharper in small, thin men, and flatter in large, stout men. For the relations of the curve to the symphysis and its axis see Fig. 157. The subpubic curve belongs to the fixed portion of the urethra, and hence metal urethral instruments are made with a definite curve to allow them to take the curve of the urethra without letting the tip impinge or catch on the floor. It is possible to pass a stiff, straight instrument or a straight one with a slight terminal bend into the bladder, but not without painful tension of the connections of the urethra, especially the suspensory ligament, and hence it is often done under anesthesia and only for certain objects, as cystoscopy, litholapaxy, etc. The pain may be diminished by pressing downward on both sides of the root of the penis and thus flattening the anterior end of the curve by slightly elongating the suspensory ligament.

The *division* into **anterior and posterior** urethræ occurs between the membranous and the bulbous portions, at the level of the superficial layer of the triangular ligament. This division is of *practical importance* from a pathological, prognostic, and therapeutic standpoint. The discharge from a *urethritis of the anterior urethra* drips from the meatus, and injections into this part escape at the same point. A urethritis also is often limited to this part, for the compressor urethræ muscle offers an obstacle to its further extension. Among the chief symptoms are: (1) Ardor urinæ, due chiefly to the contact of the acid urine with the inflamed mucosa; (2) frequent painful erection. The common causes of erection (p. 463) are excited by the inflammation, and the pain is due to the loss of elasticity of the mucosa. The complications of such an anterior urethritis are principally chordee, gleet, and stricture. When an *inflammation* extends into the *posterior urethra* or an injecting catheter is introduced beyond the compressor urethræ muscle, the discharge or injection above this muscle flows into the bladder and does not appear at the meatus. Frequent urination and tenesmus are prominent symptoms. The normal desire to urinate when urine enters the prostatic urethra is made uncontrollable on account of the sensitiveness of the inflamed prostatic mucosa. The inflammation here is also liable to spread to the bladder, vas deferens, epididymis seminal vesicles, prostate, and kidneys by continuous extension or otherwise, hence the prognosis of posterior urethritis is more grave. By using considerable pressure and preventing the escape at the meatus, fluid may be injected into the bladder from any point in the anterior urethra.

Embryologically also the posterior urethra is of a different formation (*i. e.*, from the urogenital sinus), and corresponds to the urethra and vestibule in the female, while the anterior urethra is formed by the genital folds of the external genitals.

The **length** of the urethra from the internal to the external meatus

varies, but averages about 17.5 cm. (7 in.) in the adult. It varies with the length of the penis; when the latter is contracted to the utmost it may be considerably (over 2.5 cm.) shorter; when the penis is more or less erected, or is pulled upon during catheterization, the urethra may measure 20 cm. (8 in.) or more. Hypertrophy of the prostate also lengthens the urethra, a fact which is useful in the diagnosis of this condition. The length of the urethra at birth is 5 to 6 cm.; in children of five years, 8 to 10 cm.; at the beginning of puberty, 10 to 12 cm.

The normal **caliber or diameter** of the urethra, being that of a cylinder which separates the walls without stretching them, can only be given approximately except for the external meatus. Sappey states that, exclusive of the meatus, the *urethral circumference* ranges between 15 and 18 mm., so that a No. 15 (French) sound could be passed without stretching the canal. The *meatus* is about 6 mm. ($\frac{1}{4}$ in.) in its long diameter. Of more practical importance are the **absolute** and **relative distensibility**. The former is represented by a cylinder averaging 10.5 mm. in its diameter (Joessel, Waldeyer). The distensibility *varies* in different parts, and as we pass from end to end of the urethra we find that a *narrow portion alternates with a wider portion.* Thus the narrow portions are, in order, the external meatus, spongy portion, membranous portion, and internal meatus; the wider portions are the fossa navicularis, the bulbous portion, and the prostatic portion. In order of distensibility we find the meatus the least distensible, next the membranous portion, the spongy portion, the bulbous portion, and lastly the prostatic portion, which is the most distensible. The different parts should distend so as to admit the following sounds of the French scale: the meatus, No. 24; the spongy portion, Nos. 28 to 30; the bulbous portion, No. 32; the membranous portion, Nos. 26 to 27; and the prostatic portion, Nos. 32 to 34.

Otis proved that the distensibility of the urethra was greater than formerly supposed, though Guyon showed that by the passage of large sounds, 31 to 34 (French), on the cadaver lacerations were produced, especially on the floor of the penile portion. According to Otis, there exists a constant *ratio of nine to four between* the circumference of the *penis* and that of the distended *urethra.* Apart from the fact that it is improbable that such an exact mathematical ratio is constant, it is difficult in measuring an organ, so variable in size as the penis, to measure the latter in the same condition of relative size in different cases. Though the caliber is not as large as the above ratio would indicate, still Otis' law is of value as a practical guide to the surgeon.

The **relative position** of some parts of the urethra may be more fully given. The **internal meatus** is on a level with the middle of the symphysis, or somewhat below or above it. It lies above this point in young subjects, and not infrequently in adults. The **prostatic portion,** in whole or in great part, lies above the horizontal plane passing through the bottom of the symphysis, so that this portion is often entirely behind the symphysis. The **deepest point** of the **subpubic curve** is in the bulb, and lies 18 to 20 mm. from the subpubic angle, usually more or less

behind the vertical plane of this angle, but sometimes beneath or even in front of it. We have already referred to the effect on the frequency of stricture here of its being the most dependent point of the curve in the erect posture. The **prepubic curve** lies below the horizontal plane of the subpubic angle, and usually 5 to 6 mm. ($\frac{1}{5}$ to $\frac{1}{4}$ in.) above the lowest level of the urethra in the bulb, so that from the latter the urethra extends slightly upward as well as forward, though it may be horizontal. *Between* the *subpubic curve of the urethra and the symphysis* lie the dorsal vein of the penis and the pudendal plexus.

On **cross-section** the empty urethra is represented by a fissure which is vertical at the external meatus, transverse in the spongy portion, stellate in the membranous portion, and like an inverted U in the prostatic portion. A form of rifling is involved by this progressive change in shape, which may account for the spiral form of the normal stream of urine. In addition the mucous membrane of the collapsed urethra is in longitudinal folds.

Sphincters of the Urethra.—The fixed portion of the urethra passes through a continuous layer of encircling muscle fibers, both plain and striated. This is formed of several parts, of which the most distal is the bulbocavernous muscle. The **internal sphincter** is composed of plain muscle fibers, derived from the deep layers of the trigonum, which pass downward and forward, obliquely encircling the upper part of the prostatic urethra. This does not include, but is *below*, the circular fibers of the bladder, which are aggregated around the internal meatus and form a ring, the "*annulus urethralis.*" The **external or voluntary sphincter** is composed of striated fibers surrounding the urethra at the apex of the prostate and continuous below with the compressor urethræ. When the bladder becomes distended the internal sphincter yields so that urine enters the upper part of the prostatic urethra, where it excites the desire to urinate, which is resisted by the voluntary action of the external sphincter and the compressor urethræ.

The urethral walls also contain *unstriped longitudinal fibers*, continuous with those of the bladder, and some circular fibers, as far as the lower end of the bulbous portion. There is but little muscular tissue in the walls of the movable portion (pars mobilis). The muscular tissue of the urethra appears to have a *peristaltic action*, whereby a catheter left in the urethra or the last drops of urine are gradually expelled. Cases of *reverse peristalsis* are also known where a flexible instrument insecurely tied has been pressed into the bladder. As already noted, the *compressor urethræ* is the dividing line between the anterior and the posterior urethra, and is also the cause of *spasmodic stricture*. The latter is usually due to a reflex from some point of irritation in the urethra (stricture, granular patch, etc.), and is often caused by the rough use of instruments; occasionally it may be due to an abnormally small meatus. It may also be due to irritation of the prostatic urethra, as from inflammation or from distention of the bladder. It commonly yields to steady, easy pressure. The retention of urine following operations on the rectum, anus, etc., is thought by many to be the result of vesical inhibition rather than of urethral spasm.

The lymphatics of the spongy portion communicate with those of the glans and enter the supero-internal group of inguinal nodes; those of the rest of the urethra enter the internal iliac nodes. A bubo may result from the infection of the anterior urethra, or from retention of discharge between the glans and prepuce, causing balanitis.

Changes According to Age.—In *children* the urethra is *shorter* (see p. 458) and *narrower*, but Keegan has shown that the urethra of a male infant one year old will admit instruments for litholapaxy, and that at two to three years of age a No. 9 and at eight to ten years a No. 11 lithotrite may be passed. Hence lithotrity and litholapaxy may be performed upon quite young infants. The *subpubic curve* in infants is also sharper, owing to the high position of the bladder. In *old age* there occurs a dilatation of the fossa of the bulb and, in cases of enlarged prostate, a lengthening and narrowing of the prostatic portion, often with an increased forward curve of the vesical end, which tends to make the tip of instruments catch on the floor, in the prostatic sinus.

Catheterization.—Catheterization, or the introduction of instruments, is of such importance that we may repeat what has been said in different places above. To catheterize properly we must know the differences in direction, mobility, dilatability, and contractility of the several portions of the urethra, for direction, not force, is requisite, and the sound must follow a passage, not force one. Use the largest instrument that will readily pass, as it is safer and easier and sometimes passes where smaller sizes will not. In the *spongy urethra* pass the instrument, especially if it be small, along the floor to avoid catching the tip in the lacuna magna, or in the dorsal row of large lacunæ behind it. The *movable urethra* (pars mobilis) accommodates itself to the shape and direction of the instrument, which is commonly held over and parallel to Poupart's ligament, the penis being held upward and to either side to obliterate the prepubic curve. When the *bulb* is reached the handle of the instrument, now held in the median line, is brought forward and pressed downward to elevate the tip to the roof so as to find the opening into the *membranous portion*. The finger in the rectum or perineum may also help to raise the tip of the instrument. If *spasm* exists use only slight steady pressure, principally the weight of the instrument; never press hard. Most *false passages* start from the depressed floor of the fossa bulbi, posteriorly. The tip of the instrument should continue to follow the roof of the membranous and *prostatic urethræ* so as to follow the curve of the urethra and to avoid the utricle and prostatic sinuses; this is done by a gentle depression of the handle. Remember that the urethral curve remains regular only along the superior wall; the dilatations are along the floor.

The urethra may be **ruptured** by being crushed between the pubic arch and a hard substance, astride of which the patient falls; also by sharp fragments in fractures of the pelvis. The parts of the urethra most often injured are the membranous portion in pelvic fractures and the bulbous portion in falls or blows on the perineum. A considerable length of the spongy urethra may be crushed. In the membranous

urethra the rupture is commonly complete, on account of its fixity and its thin walls.

The commonest pathological conditions that affect the urethra are urethritis, usually gonorrheal, and its sequelæ, gleet and organic *stricture*. The latter, as stated above, is most common in the bulbous and membranous portions, as is also traumatic stricture following rupture of the urethra. The obstinacy of a urethritis in yielding to treatment is in part due to the length and narrowness of the canal, to the dilated portions which serve as reservoirs for secretion, but especially to the numerous folds, lacunæ, and glands, in which the infection may remain chronic or dormant.

The Penis.—The **skin** covering the body of the organ is continuous with that of the scrotum and is destitute of fat, highly elastic, thin, and very movable, thus allowing its changes in size. Owing to its movability, due to the looseness of the subcutaneous tissue, the skin should not be drawn too strongly downward over the glans in circumcision or amputation of the penis, otherwise the operator may be startled by seeing the skin above the section retract to the base of the organ. In very large scrotal herniæ or hydroceles the skin and loose subcutaneous tissue of the penis may be drawn upon to such an extent to cover the scrotal mass that the penis disappears and is represented by a mere depression in this mass from which the urine escapes.

From the cervix or coronary sulcus the skin extends down over but outside of the glans a variable distance and is then doubled upon itself to form the **prepuce or foreskin**. The **inner layer** of the prepuce is attached more or less firmly around the cervix, to be thence continued over the glans, at the end of which, dipping into the meatus for 6 mm. ($\frac{1}{4}$ in.), it is continuous with the urethral mucosa. The prepuce *at birth* is relatively very long, more than covering the glans.

When the prepuce is so tight as to prevent its easy retraction the condition is called **phimosis**. The preputial orifice may only admit a small probe, or, rarely, may be completely closed. Phimosis may cause *difficult micturition* if the opening at the end of the prepuce is very small, and in any case *balanoposthitis* is likely to occur, which is due to secretions and urine retained beneath the prepuce, and is followed by adhesions of the prepuce to the glans. Incomplete development of the glans, vesical and urethral irritation with incontinence of urine, especially nocturnal, hernia, prolapsus recti, and greater liability to contract venereal diseases may also result from phimosis. A long series of reflex nervous conditions, spastic palsies, joint deformities, etc., has been attributed to the same cause, often without sufficient reason. Besides the congenital form, phimosis may also be acquired as the result of inflammatory swelling, due to the presence of ulcers or balanitis beneath the prepuce.

Owing to the serious conditions resulting from phimosis, it requires appropriate **treatment**. In many cases of congenital phimosis *stretching* the prepuce may be all that is necessary, in others a little *dorsal slit* is sufficient, while still others with a long narrow foreskin require

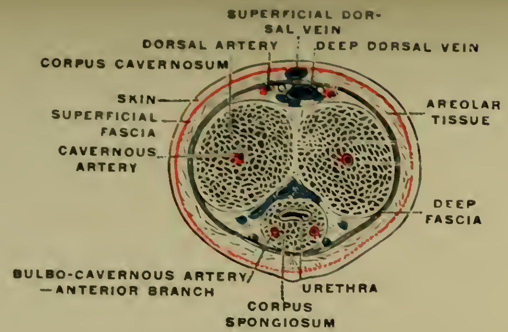
circumcision. The main object of this is to uncover the glans. It is unnecessary, if it were possible, to divide the two preputial layers at the same level. No special instruments are required. We divide the outer layer at the proper level, then slit up the inner layer, which covers the glans, on its dorsum. Then we can loosen the adhesions between the foreskin and the glans when present. We leave a cuff of the inner layer of varying size and suture the two layers, remembering that, as the inner layer is closely attached around the neck, the length of this cuff determines the distance of the scar from the cervix and the end of the glans, and that if too much of a cuff is left, some degree of phimosis is sure to persist. The region of the frenum is the most vascular (artery of the frenum), so that careful hemostasis and the removal of any redundant cellular tissue is necessary to avoid the formation of an awkward fibrous lump. It is interesting to note that shortly before and usually at birth the inner layer of the foreskin and the glans are adherent throughout. Normally, their separation occurs during infancy spontaneously from erections or from the mechanical retraction in bathing, unless the prepuce is very narrow.

When a foreskin, narrow from birth, or narrow and inelastic as the result of inflammation, is forcibly retracted over the glans it may remain caught in the cervix owing to the difficulty of pulling it down over the corona. The pressure of the narrowest part, the preputial margin, especially if inelastic, causes the glans to swell, which decreases the chance of reduction and increases the pressure, so that sloughing may occur at the line of pressure. This condition, called **paraphimosis,** demands relief to save the preputial band or even the glans, etc., from sloughing. We may sometimes replace the foreskin after reducing the size of the glans by pressure, but other cases require a longitudinal incision of the constricting band on the dorsum, from beneath or above it. The constricting preputial margin forms a deep furrow, often ulcerated, with a swollen, edematous fold of skin on either side of it. The lower fold may even overlap the glans somewhat and cover a second furrow, the coronary sulcus, deepened by the surrounding swelling. In the median line, on the under surface of the penis, there is the indication of a *median raphê,* continuous with that of the scrotum, along which the coverings of the penis are more or less adherent together.

The skin is lined by a thin **dartos,** a muscular layer with longitudinal fibers continuous with the dartos of the scrotum. At the end of the prepuce the muscular fibers are arranged circularly, forming a kind of *sphincter.* The dartos lines both layers of the prepuce, between which is an extension of the **loose subcutaneous tissue,** which connects the skin and dartos loosely with the fascia penis and renders the former so *movable.* This loose tissue accounts for the *sudden and great swelling* that may occur in the prepuce or on the penis as the result of inflammation, edema, or the extravasation of blood, urine, etc. The *superficial vessels and nerves* are contained in this loose tissue, hence it should not be removed in circumcision. The skin covering the neck and the proximal side of the corona is lined by this loose tissue, but there is no subcutaneous

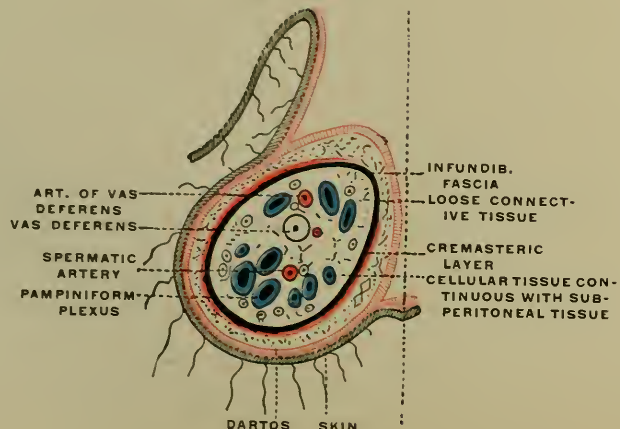
PLATE XLVI

FIG. 159



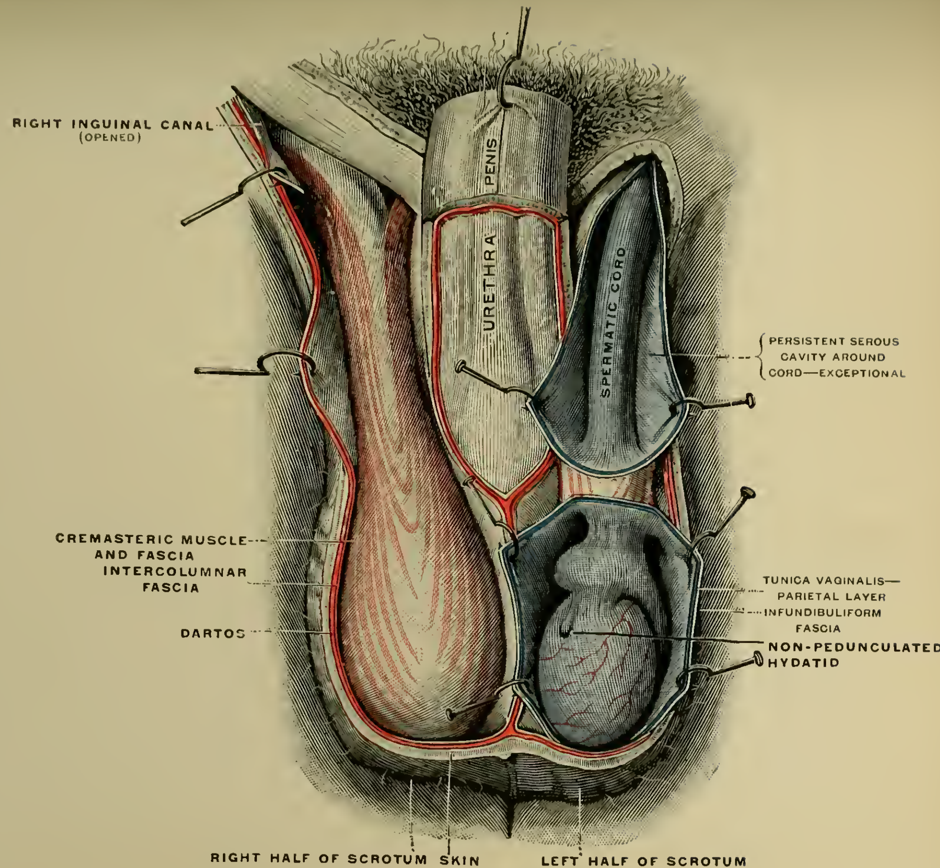
The Penis in Transverse Section, showing the bloodvessels and the several layers. (Gerrish, after Testut.)

FIG. 161



Transverse Section of the Right Spermatic Cord with the Layers of the Scrotum Covering It.

FIG. 160



The Scrotum. (Gerrish, after Testut.)

On the left side the cavity of the tunica vaginalis has been opened; on the right side only the layers superficial to the cremaster have been removed.

tissue over the glans. This accounts for the fact that a *chancre* on the glans shows but little if any induration (parchment induration), while a chancre on the neck or the proximal side of the corona, a favorite position, has a typical induration of the base, due to the infiltration of the subcutaneous connective tissue.

The **fascia penis** is the highly elastic fibrous sheath investing the three erectile bodies which form the bulk of the penis. It extends as far as the neck, around which it is firmly attached to the erectile bodies and fuses with the skin. At the base of the pendulous portion of the penis this fascia is continuous with the suspensory ligament in front and the deep layer of the superficial perineal fascia behind, and limits the forward extension of extravasations under the latter fascia. It covers the deep dorsal vessels and the lateral tributaries of the dorsal vein, by compressing which it contributes to the **erection** of the penis, after this condition has once become established. In this it is aided by those fibers of the bulbocavernosi and the ischiocavernosi which encircle the dorsum of the corpora cavernosa and thus compress the dorsal vein. The contraction of the compressor urethræ muscle and the pressure of the penis against the pubic arch by means of the ischiocavernosi muscles also compress this vein and thus assist in erection of the penis. Apart from these causes of erection, which act by hindering the venous return, the vasodilator nerves act by increasing the arterial supply of the erectile bodies through the dorsal arteries, the arteries of the bulb and of the corpora cavernosa. The *spinal centre of erection* is in the lumbar enlargement (first three sacral segments) and may be stimulated by any local irritation; it also receives exciting and inhibitory stimuli from the brain. When the cerebral inhibitory action is shut off, by an injury or disease of the spinal cord above this centre, a condition of chronic partial erection, known as *priapism*, is likely to occur.

Besides the active erection, in which arterial supply and venous return are both concerned, there may be a *passive erection*, such as that due to the pressure of a full bladder on the venous plexus (prostaticovesical) through which the dorsal vein of the penis empties into the branches of the internal iliac vein. The proposal to tie the dorsal vein to assist an incomplete erection of the penis has been tried with some success. A constricting band around the penis causes rapid and extensive swelling of the organ, hence in tying in a catheter it is best not to employ tapes around the penis, and no bandage around the penis should be tight. The large, deep *dorsal vein* (Fig. 159) of the penis is usually single and occupies the groove between the two corpora cavernosa superiorly. It pierces the triangular ligament 12 mm. ($\frac{1}{2}$ in.) below the pubic arch. The thick, elastic sheath of the corpora cavernosa, called the *tunica albuginea* from its whitish appearance, consists of an outer layer of longitudinal fibers covering both corpora and an inner layer of circular fibers forming a separate sheath for each. The latter forms a septum between the two which is incomplete anteriorly, so that any inequality in the blood supply of the two corpora may be equalized.

The **suspensory ligament** of the penis connects the corpora cavernosa

with the front of the symphysis pubis. In front of this ligament we have the movable portion or "*body*" of the penis, which serves as the pars copulatrix and corresponds to the pars mobilis of the urethra. The **angle** of the penis, immediately in front of the suspensory ligament, is only present in the flaccid condition of the organ. In erection the "body" of the penis comes into line with the "*root*," which corresponds to the two crura of the corpora cavernosa which, diverging behind the suspensory ligament, are attached to the ischiopubic rami.

Each *corpus cavernosum* measures about 15 x 1.2 cm. (6 x $\frac{1}{2}$ in.), which increases by a third or more in erection. The *corpus spongiosum* begins behind in an enlargement, the bulb, surrounding the floor and sides, and, farther forward, the entire urethra. It ends in front in a conical cap, the glans penis, which covers the rounded anterior extremities of the corpora cavernosa. The **bulb**, measuring 3.7 cm. ($1\frac{1}{2}$ in.) long and 18 mm. ($\frac{3}{4}$ in.) broad, abuts against the central point of the perineum, 2.5 to 3.5 cm. (1 to $1\frac{1}{2}$ in.) in front of the anus. It presents inferiorly an incomplete median septum, indicated on the surface by a slight furrow; hence if the bulb is incised in the exact median line the bleeding is less than it otherwise would be. The bulb is invested by a fibromuscular sheath, continuous with the superficial layer of the triangular ligament, and by the *bulbocavernosus muscle,* whose *action* assists in ejaculation, in expelling the last drops of urine, and in the erection of the penis. The **glans** is twice as long on its upper as on its under surface, and its projecting base or corona, which limits the neck, is interrupted in the median line inferiorly by a small median fold, the **frenum preputii,** continuous with the inner layer of the prepuce. The frenum grooves the under surface of the glans as far as the inferior angle of the meatus, and contains vessels of some size which, if ruptured in coitus, in case the frenum is unusually short, or eroded by chancroidal ulceration, may cause considerable loss of blood. They may require hemostasis in circumcision. In erection both the glans and the rest of the corpus spongiosum are soft as compared with the corpora cavernosa, and thus they offer no resistance to the passage of semen or urine.

When a urethritis extends beyond the mucosa and causes an induration of the submucous structures, or, still further, to the trabeculæ of the corpus spongiosum, and the spaces of the erectile tissue become filled by an exudate, the corpus spongiosum loses its elasticity, so that in erection it cannot elongate, but acts like the string of a bow and bends down the corpora cavernosa, so that the erected penis is curved backward. This condition, known as **chordee,** is very painful, owing to the traction on the inflamed urethra and corpus spongiosum. The erected corpora cavernosa may be "*fractured*" by forcible flexion in coitus and otherwise. Such an injury is irreparable; it causes an extravasation of blood, interrupts the continuity of the erectile tissue, so that erection in front of the break is impossible, and it prevents the straight erection of the penis, for the corpus cavernosum so affected can not lengthen as much as the other; or if both are affected, the portion of both distal to the break cannot become erected.

Lymphatics.—The lymphatics of the penis, including those of the urethral mucosa, enter the middle group of the superficial inguinal lymph nodes. Those from the glans enter the deep inguinal and lowermost iliac nodes. As cancer of the penis commonly originates in the glans, the deep nodes may be involved as soon as or before the superficial nodes. The lymph trunks pass up the dorsum of the penis, where they may be felt in lympangitis.

Congenital Malformations.—**Hypospadias,** the commonest form, is *due to* a partial or complete failure to unite, on the part of the genital folds, on the under aspect of the penis. These folds by their union convert the groove between them into the spongy portion of the urethra. This failure to unite may affect the entire length of the spongy urethra, so that the urethral opening is in the perineum; or it may occur at the end and involve only the glans, so that the opening is just back of the glans; or it may occur at any intermediate point. In *complete hypospadias,* and to a less extent in other forms, the corpus spongiosum is wanting or defective, being replaced largely by fibrous tissue which does not lengthen in erection of the penis, so that in this condition the penis is bent sharply downward and backward. Complete hypospadias is often accompanied by a cleft scrotum and perhaps by an empty scrotum, and is then one of the elements which go to make up *pseudo-hermaphroditism.*

Epispadias is due to a failure of more or less of the urethra to close on its upper aspect. The *opening* is usually found in front of the symphysis, and the condition is often associated with a separation of the symphysis and exstrophy of the bladder; hence it is due to malformation at an early period of development. It is more difficult to explain embryologically.

Besides being the most frequent situation for chancroid, condylomata, and the initial lesion of syphilis, the distal portion of the penis may be affected by cancer. This commonly takes the form of epithelioma of the glans or prepuce, and most cases are said to occur when phimosis exists or has existed. The inguinal nodes may be involved early, and should always be removed. (See Lymphatics, above.)

The Scrotum.—Although in descriptive anatomy this term is often applied to the skin and dartos only, yet topographically we must consider with it the other envelopes of the testicle and of the lower part of the spermatic cord. The lax scrotum is admirably suited to *protect the testicles* by allowing them to move about so readily and thus to escape injury. The *left half* is commonly larger than the right. In the infant the scrotum is larger above than below, vice versa in the adult. It will be noticed that the layers of the scrotum correspond to those covering the sac of an oblique inguinal hernia.

The skin is thin and transparent, showing an ecchymosis beneath it quickly and distinctly. It is very *elastic,* so that it allows of great distention, as in large herniæ, hydroceles, and tumors. It is also *redundant,* so that the loss of a portion by excision or sloughing will not be missed. Excision of redundant scrotum has been employed in the treatment of varicocele. The skin forms a *single pouch,* but a *median raphé,* continu-

ous with that on the under surface of the penis and in the perineum, indicates its embryological formation from two lateral halves. The more or less transverse *rugæ,* into which the skin is thrown by the contraction of the underlying dartos, favor the accumulation of dirt and the secretions of the sweat and sebaceous glands, the irritation due to which may account for the eczema and epitheliomata not uncommon here.

The dartos is very vascular and closely lines the skin, especially in the lower part of the scrotum. Its dark reddish color depends upon the longitudinally disposed unstriped muscle fibers that it contains, the contraction of which causes the transverse *rugæ* of the skin. These rugæ are a sign of health; they disappear in old age, in enfeebled conditions, or under the relaxing effects of heat, and the scrotum becomes smooth and pendulous. Warm applications relax the dartos, and thus may prevent the inversion of the edge of an incised wound of the scrotum, which interferes with its proper suture. *In wounds* of the scrotum, especially with loss of substance, the *contraction* of the dartos is of value in closing the gap. Such a contraction may be stimulated by cold applications, sexual excitement, mental emotions, and by slight friction, but not by electricity. Its contraction is slow and peristaltic, and shortens the scrotal pouch. The scrotum, after the cure of hydrocele or hernia, is enabled to regain its normal size by the contractility of this tissue. The dartos forms a *separate pouch* for each testis, and the median meeting of these two sacs forms the *septum scroti,* which extends from the raphé of the skin to the root of the penis. The dartos is *continuous* with the superficial fascia of the abdomen and perineum and with the dartos of the penis, and, like the latter, contains no fat.

The *skin* and *dartos* form practically a *single layer,* connected by a loose connective-tissue layer with a composite layer formed by the other envelopes of the testicle, etc. For practical and surgical purposes the testis, etc., is covered by only two composite layers, loosely united by this loose connective-tissue layer. This loose fatless **connective tissue layer** allows large *extravasations* of blood to occur after injuries. Owing to the dependent position of the scrotum, this tissue may early become very edematous in a case of dropsy. It allows the testis and cord and their envelopes to be enucleated through an incision or protruded through a wound of the scrotum proper. It is continuous with a similar layer in the penis, and thus extravasations of urine or of any sort may readily extend from the scrotum to the penis, and vice versa. By some this layer is regarded as *continuous with* the intercolumnar fascia at the external ring, and hence as being the *external spermatic fascia,* while others describe the latter as more membranous and as forming a fascial covering of the cremaster muscle, most distinct above.

The **cremasteric and infundibuliform layers,** continuous in the inguinal canal with the internal oblique muscle and the infundibuliform fascia respectively, are lined by the parietal layer of the tunica vaginalis and form a composite envelope for the testis. This envelope is connected by the loose connective-tissue layer with the scrotum proper, and hence

is readily separable from the latter, except at the scrotal ligament, inferiorly.

The cremaster is a voluntary muscle occurring in scattered, arched bundles, bound together by thin, connective-tissue laminæ, which also form the sheaths of the muscular bundles. These bundles lie mostly in front of and below the sac formed by the next layer. It is *supplied by* the genital branch of the genitocrural nerve. Its *contraction* suddenly raises the testis and its inner coverings within the scrotal pouch. The **cremasteric reflex** is the reflex contraction of this muscle following stimulation, as by scratching, of the skin of the upper and anterior aspect of the thigh, which is supplied by the sensory or crural branch of this nerve. The muscle becomes *hypertrophied* when the size or weight of the enclosed mass is increased, as in large herniæ, etc. According to Toldt, its contraction favors the venous circulation within the scrotum and helps to press out the contents of the epididymis.

The infundibuliform fascia (*internal spermatic fascia*), by its direct connection with the lower part of the posterior border of the testis, anchors the latter in the postero-inferior part of the scrotum, so that it retains this position when the cavity of the tunica vaginalis is filled with the fluid of a hydrocele or a hematocele. Hence we *puncture a hydrocele* in front and above, to be out of reach of the testis. At the point of attachment of the testis the infundibuliform fascia is also adherent to the external layers, and is assisted in anchoring the testis by a fibromuscular band, the *scrotal ligament*, which represents the remains of the gubernaculum testis, connecting the lower end of the epididymis with the scrotal wall.

Loose areolar tissue, continuous with the *subperitoneal connective tissue*, *connects* the infundibuliform fascia with the tunica vaginalis and *binds together* the various elements of the spermatic cord. In the latter situation it contains some fat, and is the seat of the *fatty tumors of the cord*, which occasionally simulate an inguinal hernia. This layer, together with the infundibuliform fascia, is known as the *fascia propria of Cooper*, who described it as very strong in large, old herniæ. A muscular band in this subserous layer (*middle cremaster*) is said sometimes to groove a hydrocele so as to partly divide it. The **parietal layer** of the **tunica vaginalis** extends for 12 mm. ($\frac{1}{2}$ in.) above the level of the testis, forming a cul-de-sac at the beginning of the cord.

The two composite layers of the coverings of the testis have a separate **blood supply**, with *anastomoses* between the two layers, and with the blood supply of the testis, in the scrotal ligament at the base of the scrotum. The anastomosis between the two halves of the scrotum is quite free. The skin and dartos are supplied by the *pudic vessels* (external pudic and the superficial branch of the internal pudic), the envelopes of the testicle by the *cremasteric vessels.* Although the scrotum is very vascular, its vitality is not great, so that it may slough from severe inflammation or pressure, hence *strapping*, if employed at all, should be applied with care, for it has been followed by extensive sloughing. The large, superficial, and often tortuous veins of the

scrotum, which are visible through the skin, should be avoided in tapping a hydrocele. They end in the internal saphenous vein, but communicate with the spermatic veins.

The *lymphatics* of the scrotum pass to the supero-internal and the inferior groups of superficial inguinal lymph nodes. These nodes are involved in diseases of the testicle, as a rule, only when the scrotum is also involved. *Elephantiasis,* a disease marked by great hyperplasia of connective tissue and due to the irritation of filaria in the lymph vessels, occurs most frequently in the scrotum. The skin and dartos receive their **nerve supply** from the internal pudic and small sciatic nerves, etc.; the ilio-inguinal and the genitocrural do not supply the skin of the scrotum (Cushing). **Embryologically,** the scrotum, like the labia majora, is formed by the *genital ridge,* the two sides of which unite together mesially to form the scrotum. Failure of this union is one of the features of so-called hermaphroditism in certain of its forms. In these cases the ununited halves of the scrotum resemble the labia.

The Testis.—**Position** (Fig. 160).—The testes are normally situated in the lower end of each half of the scrotal pouch, where they are suspended by the spermatic cords at *unequal levels,* the left being commonly lower than the right, owing to the greater length of the left spermatic cord. This enables the testes to avoid pressure from each other. The testis is *held in position* and anchored to the postero-inferior part of the scrotum by the scrotal ligament, by its attachment to the infundibuliform fascia along the lower part of its posterior or straighter border, and by the reflection of the visceral layer of the tunica vaginalis to join the parietal layer postero-inferiorly. Hence when the vaginal sac is filled with fluid, as in hydrocele or hematocele, the testis occupies a *postero-inferior position* in the sac, and we can safely puncture the sac in front or above. In some cases the testis is rotated on its vertical axis and attached antero-inferiorly (*inversion of the testis*), but in such a case we can still safely tap a hydrocele above and in front or at the side. In other cases the testis may lie horizontally with the epididymis above or below (Kocher). Torsion of the testis and cord in either direction on the longitudinal axis is an uncommon accident, which may cause merely an infiltration of the epididymis or, if severe, gangrene of the testis, etc. It probably depends upon a congenital malformation or partial descent of the testis, as a normally placed testis cannot be twisted.

Development and Descent.—In early fetal life the testis is developed internal to the lower end of the kidney at the level of the first and second lumbar vertebræ, hence the origin of the spermatic vessels in this region. It lies behind the peritoneum, or with a short mesentery of peritoneum (mesorchium), and to its lower end is attached a fibromuscular band, the *gubernaculum testis* (rudder of the testis), whose three-tailed lower end is attached to the dartos at the bottom of the scrotum and to the two pillars of the external abdominal ring. Beginning to descend in the second month of fetal life, it retains a position near the internal ring from the end of the third to the end of the sixth month. Then, preceded by a pouch of peritoneum from this part (*processus vaginalis*), which

pushes before it a sheath from each of the layers of the abdominal wall through which it passes, the testis reaches the external ring at the eighth month and the bottom of the scrotum shortly before birth, but occasionally not until after birth. Hence the presence of the testis in the scrotum is an indication of the maturity of a male fetus. The *cause* of this "descent of the testis" is uncertain, but it is probably partly due to the development of the pelvic and lumbar regions, which grow upward away from the testis, anchored by the gubernaculum, and partly to the contraction or atrophy of the latter, for the first cause would not take it beyond the internal ring at most.

One or both testes may be *arrested in their descent* in the abdomen, at the internal ring, in the inguinal canal, or just outside of the latter. When the testes have not passed the external ring the condition is called *ectopia testis* or *cryptorchism* (normal in certain animals, elephants, etc.), which may be unilateral or bilateral. Inguinal retention (*i. e.* in the inguinal canal) is the commonest form. Retention of the testes has been attributed to adhesions from prenatal peritonitis, shortness of the cord, and small size of the external ring. The vas often descends below the testes and then turns back to reach the latter. A testis arrested within the canal may, and one at the external ring usually does, reach the scrotum at or before puberty. A testis retained above the external ring is *atrophic*, and is said not to be functionally active; hence it may be removed without question in an operation when it complicates a hernia. It is also said to be especially liable to malignant disease, but the statement is supported by little proof. If it is lodged in the inguinal canal it may be mistaken for and it *predisposes to a hernia*, and is subject to attacks of inflammation from pressure or injury. Such an inflamed testis may cause errors in diagnosis, being mistaken for abscess, strangulated hernia, etc., unless it is noticed that the testis of that side is wanting in the scrotum. Again the testis may become aberrant and descend into the groin through the femoral instead of the inguinal canal (femoral ectopy), or it may wander into the perineum (perineal ectopy). Exceptional attachments or irregular development of the gubernaculum account for some, at least, of the cases of ectopy of the testis.

The consistence of the testis is *firm* and *elastic*, more so when the tubules are full or in certain diseases, such as tuberculosis, syphilis, or tumors, less so before puberty or when atrophy occurs from old age or otherwise. The consistence is normally *uniform* and the surface should be *smooth*, so that when nodules or localized hardening or softening occur the testis is abnormal or diseased. Partial induration of the epididymis indicates tuberculosis or a chronic following an acute inflammation (epididymitis).

The normal **size** (4 cm. [1½ in.] in length, 3 cm. [1¼ in.] in depth, and a little less than 2.5 cm. [1 in.] in thickness) and the normal **weight** (5 to 8 drams) are not attained until after puberty, being much less before then. If there is only one testis (monorchism), an occasional occurrence, or only one descended, its size and weight may be much increased, otherwise such increase indicates a pathological condition.

The great thickness (1 mm.) of its bluish-white fibrous covering, **tunica albuginea**, prevents any sudden expansion, but allows a gradual increase in size, as in tumors or chronic inflammation. This accounts for the intense pain in acute orchitis, due to pressure on the nerve endings by the products of inflammation pent up within the unyielding capsule. If in such a case the inflammation is purulent and an opening occurs in the tunica albuginea, the tension of the inflammatory products forces out the substance of the testis, and we have **hernia** or **fungus testis**, which may go on even until all the testicular substance is extruded and only granulation tissue remains. This condition is due to the firmness of the fibrous capsule. The pain of an epididymitis, on the other hand, is much less, as the fibrous covering of the epididymis is much less thick and firm and more elastic and yielding, so that this part may swell rapidly and extensively.

The chief **relations** of the testis are with its covering, the visceral layer of the tunica vaginalis, with the epididymis, and with the cord. The testis is completely covered by the *visceral layer* of the *tunica vaginalis*, except along its posterior border, where superiorly the efferent tubules pass out into the head of the epididymis, below this the vessels enter, and inferiorly the border is adherent to the infundibuliform fascia and attached, either directly or through the lower end of the epididymis, to the scrotal ligament. Along this posterior border the visceral layer of the tunica vaginalis is continuous with the parietal layer, either directly, as on the mesial side, or after partly covering the epididymis, as on the lateral side.

Normally the two serous layers are in contact, separated by only enough fluid to moisten or lubricate them. An increase of the amount of this fluid, which may reach several ounces or even pints, constitutes a **hydrocele** or, if the fluid is largely bloody, a *hematocele*. A hydrocele is *pear-shaped*, with the small end above, and is commonly *translucent*, except where the testis lies, the normal position of which we have seen above.

The upper tubular portion of the processus vaginalis usually atrophies soon after birth to a mere fibrous band (vaginal ligament), which lies among the elements of the spermatic cord and which we can sometimes trace from the bottom of the slight depression of the peritoneum at the internal ring to the upper end of the vaginal pouch. Sometimes, however, this upper tubular portion remains open (see p. 295), in whole or in part. If the entire "processus" remains open, fluid may pass into it from the peritoneum, or may be returned into the latter by pressure or posture. It would be unsafe to inject irritant fluids into such a congenital hydrocele, owing to its connection with the peritoneal cavity. If the processus is closed above and below, or at intervals, and is open between, fluid collecting in the unclosed portions above the vaginal pouch constitutes an **encysted hydrocele of the cord**, either monolocular or multilocular. Such hydroceles, like the processus vaginalis in which they are formed, *lie* in front of the cord, and the testis can be plainly felt below the swelling if there is no vaginal hydrocele as well. An

encysted hydrocele in the canal of Nuck, which is occasionally met with, occurs in the similar process of peritoneum in the female.

The Epididymis.—The epididymis (Fig. 161) *rests upon* the posterior border and overlaps the adjoining portion of the external surface of the testis. Its enlarged upper end or head, **globus major,** projects above the upper extremity of the testis, where it is readily *felt.* It is intimately *connected with* the upper end of the posterior border by the visceral layer of the tunica vaginalis, which covers it, and by the vasa efferentia which, coiled up as the coni vasculosi, form the great bulk of the globus major. Between the body of the epididymis and the outer surface of the testis is a small fossa, the *digital fossa,* lined by the tunica vaginalis. On account of its *meso-epididymis,* connecting the body of the epididymis with the posterior border of the testis, the former is readily movable and may be pressed away from the testis and even more or less transversely placed, after stretching of this serous duplicature in large hydroceles, etc.

The lower and somewhat enlarged end or *tail,* **globus minor,** reaches nearly to the lower limit of the posterior border of the testis, to which it is loosely connected. The *tunica vaginalis* leaves uncovered most of the tail, the posterior part of the inner surface of the body, and the posterior border of the epididymis. Along the latter border and the mesial part of the posterior border of the testis the visceral is continuous with the parietal layer of the tunica vaginalis by means of two folds, between which the vessels pass to and enter the posterior borders of each organ. The globus minor is continuous with the vas deferens, hence inflammation reaching the epididymis along the vas should first affect this part. The smaller size and more tortuous course of the arteries of the epididymis appear to account for the relative frequency of its involvement in general infections. From its greater size when inflamed and swollen the globus major is much the most prominent part in epididymitis. Most of the cases of so-called swollen testis following a gonorrheal posterior urethritis, the passage of an instrument, etc., are really cases of *epididymitis,* the testis remaining unaffected. The hard and much enlarged epididymis can be felt overlapping and masking the testis behind, above, and more or less externally, while the testis is normal in size and consistence. Tuberculosis commonly attacks primarily and often exclusively the epididymis, tertiary syphilis the testis.

The Arterial Supply.—The arterial supply of the testis is from the spermatic artery with some anastomotic supply from the artery of the vas. The veins enter the spermatic or pampiniform plexus. When varicosity of this plexus occurs before adolescence, or when it exists for a long time, it may cause atrophy of the testis. The elevation of the scrotum, practised in all inflammations of the epididymis and the testis, acts by diminishing the congestion by favoring the venous but not the arterial circulation. The **lymphatics** enter the lumbar nodes. The rare instances where affections of the testis involve the inguinal nodes, without first involving the scrotal coverings, are to be explained by lymphatic

anastomoses accompanying the vascular anastomoses which we know are present along the scrotal ligament, etc.

The Nerve Supply.—The association of the spermatic plexus, accompanying the spermatic artery and derived from the renal and aortic plexuses, with the abdominal sympathetic nerve centres explains (1) the pain in and retraction of the testis during the passage of a renal calculus, and (2) the sickening pain, nausea, faintness, and collapse or syncope which result from a blow on or inflammation (orchitis) of the testis. The *pain* from such a blow extends into the loins, and pain in the back, often felt in orchitis, after the injection of a hydrocele or from the dragging of a tumor of the testis, depends upon the fact that its chief source of innervation is the tenth thoracic segment. The sickening pain due to slight pressure on the testis is so characteristic as to be diagnostically useful in determining the presence or position of the testis in a swelling in the inguinal region or scrotum. Pressure on the *ovary* causes a somewhat similar pain.

Fetal Remains.—Two structures go under the name of **hydatids of Morgagni**: (1) a pediculated, pear-shaped, serous sac filled with a clear fluid, attached to the upper pole of the globus major and not always present, and (2) a fairly constantly present sessile, flattened, and often lobulated structure, containing in its centre a canal which may end blindly or on the surface. The sessile hydatid is attached to the upper end of the testis, in front of the globus major, and represents the end of the duct of Müller; hence it is homologous with the fimbriated extremity of the Fallopian tube. **The paradidymis, or organ of Giraldes,** probably derived from the tubules of the Wolffian body, usually disappears in early childhood. It appears as a yellowish-white patch, which lies outside of the parietal layer of the tunica vaginalis, on the lower part of the spermatic cord, in front of the spermatic plexus, and posterior to the globus major.

The above fetal remains, together with the vas aberrans, are of practical importance because they may give rise to *cystic tumors,* including the true *spermatic cysts* containing seminal fluid. The latter are most often formed from the tube of the epididymis, especially the globus major. The above cysts may project free into the cavity of the tunica vaginalis.

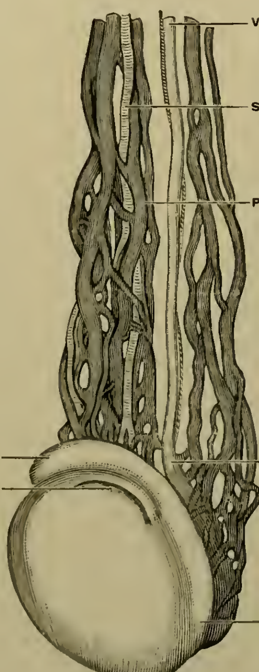
In addition to tuberculosis and syphilis the testis may be the seat of almost any *newgrowth* except lipoma. Sarcoma and chondroma are particularly common, and tumors of the testis, like those of the parotid, are very liable to be "mixed," consisting of several kinds of newgrowth. Newgrowths usually spring from the testis proper, seldom from the epididymis. *Removal of the testes* diminishes the size of the prostate, which is much atrophied in eunuchs; hence the employment of castration in the treatment of hypertrophy of the prostate, but the result appears to be only temporary. As division of the vas deferens causes atrophy of the testis, it has also been employed for the same purpose.

The Spermatic Cord.—The spermatic cord consists of (1) the vas deferens, (2) the artery of the vas deferens, (3) the spermatic artery,

(4) sympathetic nerves accompanying the arteries, (5) the veins accompanying the two arteries, (6) lymphatics running with the veins, (7) the remains of the processus vaginalis, sometimes present, and (8) the internal cremaster fibers of Henle. All these structures are *joined together* by a fatty, connective tissue, continuous with the subperitoneal tissue, which may give origin to inguinal or *scrotal lipoma,* simulating true herniæ.

The **vas deferens** *lies* to the inner side and behind the epididymis at the commencement of the cord, and bears the same relative position to the other elements of the cord above, where its hard, *cord-like feeling*

FIG. 162



Left testis with spermatic cord. Lateral view. (Joessel.)

enables it to be readily found or avoided as occasion requires (see p. 430). *In castration for* tuberculosis or tumor of the testis, etc., especially if the cord is involved, it is often advisable to remove it as high up as possible. This may be done by incising as far as the internal abdominal ring down to the peritoneum and stripping it from the underlying vas. The *two arteries* and their accompanying veins require ligation, and it is well to ligate them separately rather than to ligate the cord en masse.

The *cord is covered* by the same layers that envelop the testis, except the tunica vaginalis. Superiorly *the dartos* is *replaced by* superficial fascia, between which and the skin is a layer of subcutaneous fat. In

reaching the cord, as in operations for varicocele, branches of the external pudic, cremasteric and superficial epigastric arteries are likely to be divided, and perhaps some branches of the superficial perineal arteries.

The veins of the *spermatic or pampiniform plexus,* to the number of five or six, lie in front of and surround the spermatic artery and present frequent anastomoses. They coalesce to three or four plexiform trunks in the inguinal canal, which unite into two or three and finally near their termination into a single vein accompanying the spermatic artery in the abdomen. The *frequency of* varicosities of the spermatic veins, or **varicocele**, is *explained by* their length, dependent position, few and imperfect valves, lack of external support from the loose surrounding tissue, pressure in their passage through the inguinal canal, and their large size as compared with the arteries, which renders the blood current sluggish. The aid furnished to many veins by muscular contraction is also wanting. Those with a normally active dartos seldom have varicocele. Several facts may be given to *explain* the *greater frequency* (90 per cent.) of varicocele *on the left* side, *i. e.,* the greater length of the left spermatic cord, the pressure of the sigmoid colon, especially in cases of constipation, on the left spermatic vein, and the passage of the latter at a right angle into the renal vein, while the right vein enters the cava at an acute angle. *Congenital defects* of development may also help to explain the above features of varicocele, but this explanation is a supposition and needs explanation itself. Varicocele is especially an affection of early adult life, and often spontaneously diminishes with the diminution of sexual vigor in old age. Of the two sets of veins it is the anterior set, or the spermatic plexus accompanying the spermatic artery, which is principally or solely involved.

In **ligation or excision of these veins** we must avoid the smaller set accompanying the vas deferens, which are sufficient to carry on the venous circulation. The *spermatic artery* need not be spared from among the veins, even if it can be, for the anastomoses with the artery of the vas deferens and the scrotal arteries are sufficient to supply the testis. It is important, however, to spare the *genitocrural nerve,* which supplies the cremaster muscle, for otherwise this muscle would be paralyzed and the testis would hang lower than before. At the internal abdominal ring the cord is formed by the coming together of the vas deferens and its vessels with the spermatic vessels.

THE PERINEUM.

This corresponds to the outlet of the pelvis and includes the structures between the skin below and the pelvic floor above.

Boundaries and Surface Landmarks.—Its **bony and fibrous boundaries** form a *lozenge-shaped figure* with the symphysis in front, the coccyx behind, and the ischiopubic rami, the ischial tuberosities, and the great sacrosciatic ligaments on the sides. By deep pressure we can *feel* the bony landmarks, and in thin subjects the sciatic ligaments,

beneath the inner margins of the glutei maximi. In the erect position the *sciatic ligaments* are overlapped by the internal borders of these muscles, but not in the sitting or lithotomy position. The bony boundaries are seen to correspond with the pelvic outlet, and hence vary in size in the two sexes (see p. 401). In the male the *transverse diameter* between the ischial tuberosities, usually 9 cm. ($3\frac{1}{2}$ in.), is sometimes so narrow, 5 cm. (2 in.), as to interfere with lateral perineal incisions. The average *anteroposterior diameter* in the male is 9 cm. ($3\frac{1}{2}$ in.), but owing to the convexity of the parts the surface measures 10 cm. (4 in.).

Superficially, the male perineum is *limited* by the scrotum in front, the buttocks behind, and the thighs laterally. With the thighs together and extended the perineum appears as a furrow between them, but with the thighs flexed and abducted (lithotomy position) the perineum appears as bounded above. The **median raphe** of the skin extends forward from the anus to the scrotum and thence onto the penis. As it represents the embryonic cutaneous seam of the two halves of the perineum, *no large vessels cross it,* hence it is chosen for *incisions* when possible. It is well to remember that it may be displaced to one side by adhesions. The centre of the anus lies in a line connecting the tips of the ischial tuberosities and about 4 cm. ($1\frac{1}{2}$ in.) from the tip of the coccyx.

The **depth** of the perineum, or the distance between the surface and the pelvic floor, *varies* individually with the amount of subcutaneous fat, and locally in the different parts of the area. Thus in the posterior and lateral parts it measures 5 to 7.5 cm. (2 to 3 in.), but less than 2.5 cm. (1 in.) anteriorly. It is important to bear in mind this distance in operating on the pelvic viscera through the perineum, as in opening the bladder, etc. The **central tendinous point** of the perineum *lies* in the median line, midway between the centre of the anus and the perineoscrotal junction and 2.5 cm. (1 in.) in front of the anus. It is the *meeting point of* the bulbocavernous, superficial transversus perinei, sphincter ani and a few fibers of the levator ani muscles, and the superficial and deep perineal fasciæ. As it corresponds to the centre of the posterior edge of the deep perineal fascia (triangular ligament) the bulb and its artery are just in front of it. Hence in lithotomy and similar operations the *incision* should not commence much in front of this point. Corresponding to the bulb and the perineal portion of the corpus spongiosum, the *surface* is somewhat *elevated* in the median line in front of the central point, and this elevation may serve as a guide to the position of the bulb.

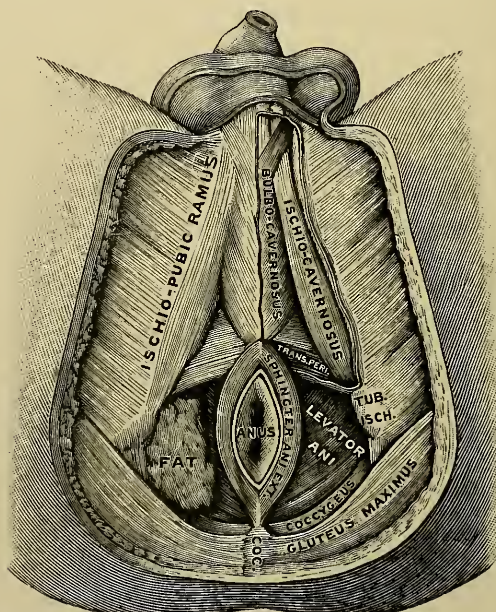
A transverse line inclined somewhat forward from the anterior part of each ischial tuberosity, passing through the "central point," divides the region into an anterior or urethral triangle (perineum proper) and a posterior or anal triangle.

The "Perineum Proper."—The "perineum proper" has the form of an equilateral triangle, measuring about 8 cm. ($3\frac{1}{4}$ in.) on all sides. The *base* is not quite straight, but inclines forward from either side to

the middle line, at the central point of the perineum. The *skin* is freely movable on the subjacent parts, and is dark and thin, readily showing any extravasation of blood beneath it. The *superficial layer* of the *superficial fascia* contains little or no *fat* in the middle line, but more fat laterally and posteriorly, where it is continuous with the subcutaneous fat of the thighs, of the ischiorectal fossæ, and of the buttocks. The *superficial lymphatics* run into the superior inguinal nodes.

Apart from the preceding layers, the perineum proper *consists of* a **triangular ledge** of tissue, *composed of* three strong layers of fascia stretching nearly horizontally between the ischiopubic rami and enclosing two interfascial spaces. It is *pierced by* the urethra and, in the female, by the vagina.

Fig. 163



Muscles of the male perineum. (Gerrish, after Testut.)

The **deep or membranous layer** of the **superficial fascia**, the fascia of Colles or "perineal fascia," turns up behind the superficial transversus perinei muscle to join the base of the triangular ligament, and thus helps to form the free posterior border of the "*perineal ledge*." It thus *shuts off* a *subfascial space* (the superficial perineal interspace) from the ischiorectal fossa behind it. This space is separated from the thighs on either side by the attachment of the fascia to the ischiopubic rami, and from the pelvis by the attachment of the triangular ligament to the same parts. Hence there is only *one outlet* for *urine extravasated* into this space, from rupture of the urethra contained within it, and that is forward to the scrotum and penis and thence, between the two pubic spines, onto the abdomen beneath the deep layer of the super-

ficial fascia, with which this perineal fascia is continuous (see p. 270). Extravasation of urine from rupture of the urethra is especially liable to occur in this space, beneath the perineal fascia, for it contains the bulbous urethra. The products of inflammation and other fluid collections take the same course.

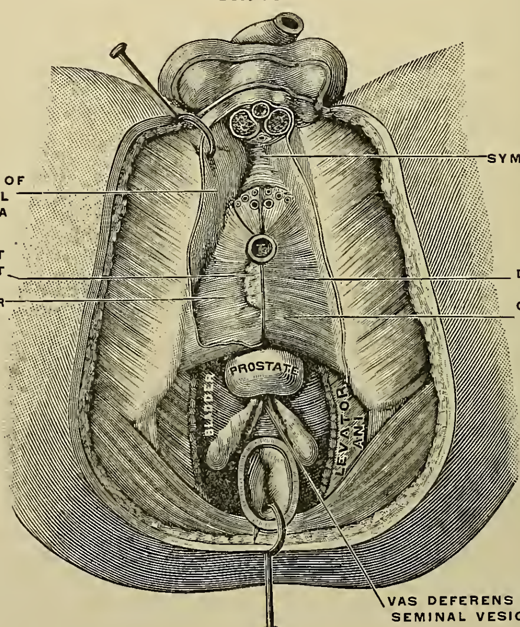
From the perineal fascia to the pelvic floor we find *alternate layers of fascia and muscle*, etc. Thus *in the subfascial space*, beneath the perineal fascia and superficial to the triangular ligament, we find the root of the penis and its muscles, vessels, and nerves, together with the superficial transversus perinei muscles and their vessels and nerves. The latter muscles, lying along the posterior boundary or base of this region, together with their accompanying vessels and nerves, serve as landmarks, and are liable to be cut into or across in lateral incisions, as in lateral lithotomy. They may be cut with impunity. Forming the root of the penis we find laterally the crura penis covered by the ischiocavernosi muscles and attached to the ischiopubic rami, and mesially the bulb covered by the bulbocavernosus. The space is divided by the bulbocavernosus into two lateral muscular triangles, bounded laterally by the erectores penis, covering the crura penis, and posteriorly by the two superficial transversus perinei muscles. Sometimes these muscles cover, or nearly cover, the entire area, and again they may leave a considerable gap between them, showing the next deeper layer, the triangular ligament, which forms the roof (often called the floor) of this space.

The triangular ligament *measures* about 3.7 cm. ($1\frac{1}{2}$ in.) from the subpubic ligament to the middle of its base, at the central point of the perineum. Its principal *function* is to support the urethra in its course beneath the symphysis. Along its base its two layers fuse with one another and with the perineal fascia, and thereby inclose the perineal interspaces posteriorly and form the free border of the perineal ledge. This border is incised in lateral and median lithotomy and in the perineal operations on the urethra, bladder, prostate, etc. The two layers of the triangular ligament separate from one another anteriorly to inclose the wedge-shaped deep perineal interspace.

The **superficial layer** *of the triangular ligament* is *pierced by* the *urethra* about 2.5 cm. (1 in.) behind the symphysis, and behind and at the sides of this opening are closely attached the bulb of the urethra and its sheath, while the *artery of the bulb* pierces it on either side of the urethral opening. It is also pierced by the *ducts of Cowper's glands* on each side of and somewhat behind the urethral aperture, and by the *vessels of the corpora cavernosa* more anteriorly and close to the lateral attachment of the ligament. *Anteriorly a small gap* is left between this layer and the subpubic ligament, through which the dorsal vessels and nerves of the penis pass from the deep to the superficial perineal interspace. The anterior part of this layer, forming the posterior boundary of the aperture for the dorsal vessels, etc., is somewhat thickened and is sometimes called the pre-urethral ligament (Joessel, Waldeyer). *Laterally* this layer is firmly attached to the ischiopubic rami, above the attachment of the perineal fascia.

The **deep perineal interspace**, between the two layers of the triangular ligament, is *wedge-shaped*, with the apex behind, where the two layers come together. It *contains* the membranous urethra (see p. 454), Cowper's glands (see p. 454), the deep transversus perinei or compressor urethræ muscle, the internal pudic vessels, nerves, and lymphatics with their terminal and deep branches (*i. e.*, to the bulb, the corpora cavernosa, and the dorsum of the penis). The **deep transversus perinei or compressor urethræ muscle** is a voluntary muscle whose inner circular fibers surround the membranous urethra and are continuous with the external sphincter vesicæ at the lower end of the prostatic

Fig. 164



Deep layer of muscles of the male perineum. On the left side of the subject the superficial layer of the triangular ligament has been removed, on the right side it is in place over the compressor urethræ or deep transversus perinei muscle. The central part of the levator ani is removed, exposing the prostate, etc. (Testut.)

urethra. The greater part of its fibers pass transversely and join an indistinct median raphé, while a few run obliquely and sagittally. They compress and help to expel the contents of the membranous urethra and of Cowper's glands, as in emission, they assist the external sphincter vesicæ, and aid the erection of the penis by compression of the veins from the bulb, the corpora cavernosa, and the dorsum of the penis, which pass through it. Some of its fibers are cut in lateral lithotomy, and, to a less extent, in many median perineal operations.

The **artery of the bulb** *runs* inward in this interspace about 12 mm. ($\frac{1}{2}$ in.), sometimes less, in front of the base of the ligament, or 3 to 3.7 cm.

($1\frac{1}{4}$ to $1\frac{1}{2}$ in.) in front of the anus. *Hence the incision* in lateral lithotomy, etc., should not be commenced more than 3 cm. ($1\frac{1}{4}$ in.) in front of the anus, to avoid wounding this artery.

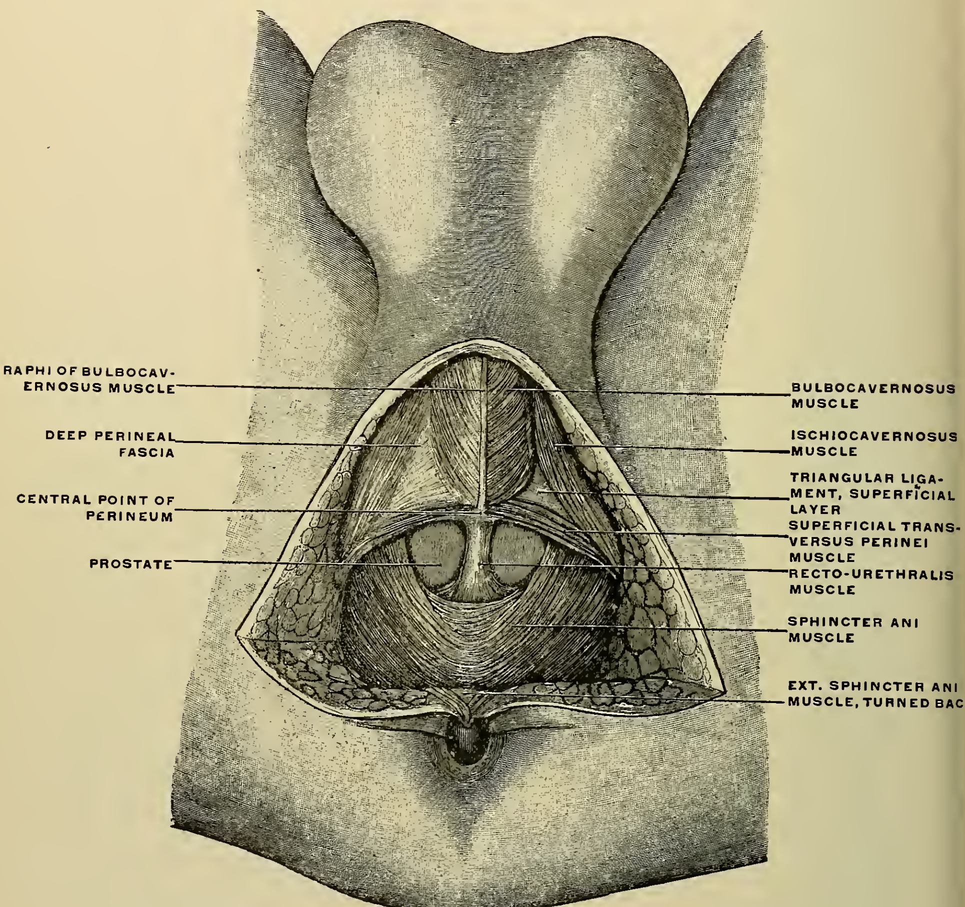
The **superior or deep layer of the triangular ligament** is *continuous* with the obturator fascia along the upper lip of the inner edge of the ischiopubic rami, where both these fasciæ are attached. It joins the superficial layer anteriorly, at the pre-urethral ligament, and posteriorly along the posterior edge of the perineal ledge. Superiorly it forms the floor of the anterior recess of the ischiorectal fossa, on either side of the prostate. The apex of the prostate rests upon it mesially, and its fibrous capsule, derived from the rectovesical fascia, fuses with it. The dorsal vein passes between it and the subpubic ligament, the pudic vessels and nerves pierce it. Incision through the posterior part of this layer on either side opens the anterior recess of the ischiorectal fossa, and then, being continued more deeply, cuts the levator ani with the anal fascia below and the rectovesical fascia above it, and thus enters the pelvic cavity. Median incision through this layer involves the prostate above it.

In **lateral lithotomy** the 5 to 7.5 cm. (2 to 3 in.) long *incision*, commenced about 3 cm. ($1\frac{1}{4}$ in.) in front of the anus and a little to the left of the median line (to avoid the bulb and its artery), is carried backward and outward to a point somewhat behind and external to the midpoint between the anus and the ischial tuberosity. Through the anterior and deeper part of the incision the knife is carried into the membranous urethra and, along the staff, through this and the prostate into the bladder. The prostate is divided obliquely backward and outward. We *divide* the skin, the superficial fasciæ, the transversus perinei muscle, vessels, and nerve, the inferior hemorrhoidal vessels and nerves, the base of the triangular ligament and compressor urethræ muscle, the membranous and prostatic urethræ, the anterior fibers of the levator ani, and the left lateral lobe of the prostate.

Parts to be Avoided.—We *avoid* wounding the *bulb* by commencing the incision to one side of the median line and by drawing the staff, and with it the bulb, well forward under the pubes. The *artery of the bulb* is avoided by commencing the incision not more than 3 cm. ($1\frac{1}{4}$ in.) in front of the anus. The *rectum* is easily avoidable if it is not distended and if the posterior part of the incision is not carried too far back or too near the median line. On the other hand, the *pudic vessels* may possibly, though not probably, be wounded if the incision is carried far to the side. If the *incision in the prostate* passes beyond the prostatic capsule, so as to incise the rectovesical fascia, it lays open the subperitoneal tissue of the pelvic cavity, the ischiorectal fossa, and the neck of the bladder into one large space. This is most likely to occur in incising the vesical outlet, for the incision into the lower end of the gland is below the reflection of the rectovesical fascia from the pelvic floor onto the prostate. If the *prostatic incision* is too vertical, the left ejaculatory duct is in danger of being incised. The lower part of the prostatic

venous plexus cannot escape. When the *accessory pudic artery* is present, it is likely to be injured, as it passes forward along the side of the prostate. *In children* lateral lithotomy or any form of perineal approach to the bladder is more difficult and objectionable, because the pelvis, pelvic outlet, and perineum are narrow; the bladder is higher up, more movable, and less strongly attached, and the prostate is rudimentary, so

Fig. 165



Male perineum.

that more of the vesical outlet itself has to be cut, while the peritoneal pouch descends lower and may be wounded. The suprapubic route, on the other hand, is easier on account of the high position of the bladder, so that it is to be preferred.

In **median lithotomy or cystotomy**, or the similar incision in external urethrotomy, perineal section, etc., the *parts divided* are (1) the skin in

the median raphé in front of the anus for 3 cm. ($1\frac{1}{4}$ in.), (2) superficial fascia, (3) sphincter ani, (4) the central point of the perineum, (5) the base of the triangular ligament and of (6) the compressor urethræ muscle, and (7) the membranous urethra. One finger in the rectum to guide the upwardly directed knife diminishes the risk of wounding the gut. There is less cutting and more dilating in median cystotomy, for the prostatic urethra and vesical outlet are only dilated and not cut. *The advantages* of the median operation consist in (1) the little bleeding, owing to the slight vascularity of the raphé and median line of the perineum, and (2) the little danger of wounding the ejaculatory ducts or the pelvic fascia, for the prostate and vesical outlet are stretched and not cut. It is an excellent operation for the extraction of small stones. On the other hand, it possesses *disadvantages* in (1) the danger of wounding the bulb, which, however, does not bleed much if incised in the exact median line, and (2) the little space obtained for the extraction of a stone. Moreover, *in children* it is *contra-indicated,* for, owing to the small size of the prostate and vesical outlet and the slight attachments of these parts, the bladder may be torn from the urethra in attempting to reach its cavity with the finger.

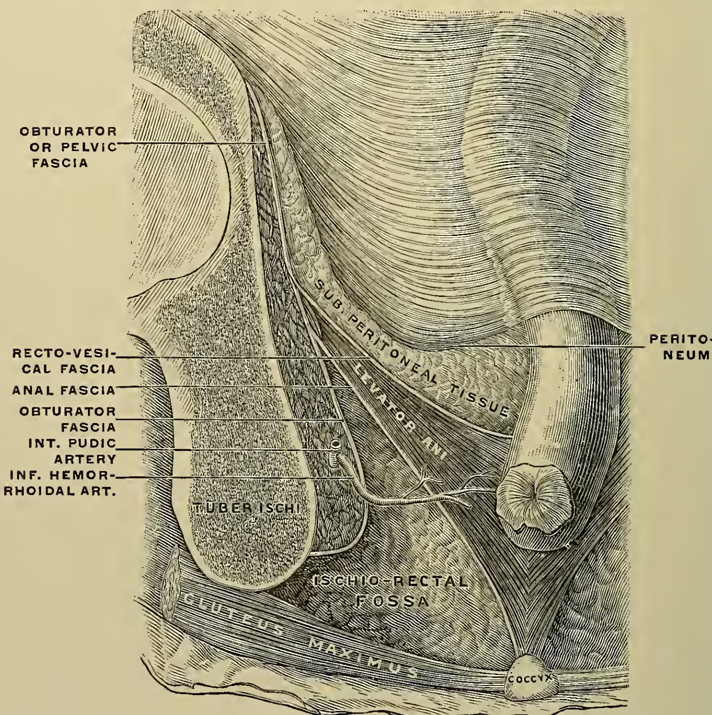
When we wish *to expose the prostate or seminal vesicles,* other perineal incisions are useful, such as the *anterior curved transverse incision* of Zuckerkandl, the inverted V or Y incision of Young, and the *median incision encircling the anus* on one side, as in v. Dittel's lateral prostatectomy. Zuckerkandl's incision is concave toward the rectum. The greater part of these incisions is in the ischiorectal region. They aim to expose the prostate after dividing the anterior fibers of the levator ani muscle. The seminal vesicles may then be exposed by separating the rectum from the prostate and bladder. In these incisions we expose the *recto-urethralis muscle* (see Fig. 165), a short muscle with rather indefinite margins, which joins the rectum and the membranous urethra in the median line. To expose the membranous urethra and the apex of the prostate by a transverse incision this muscle must be divided. Its division allows the rectum to drop back and the prostate to be separated from it. If not divided, the rectum is liable to be torn. It is made prominent by retracting the central point of the perineum forward. In all perineal operations on the male bladder it should be remembered that the vesical outlet lies 6.5 to 7.5 cm. ($2\frac{1}{2}$ to 3 in.) from the surface, in the lithotomy position. But this distance may be so increased in some cases of prostatic hypertrophy as to make the perineal route to the bladder difficult or even contra-indicated.

The Perineum in the Female.—The perineum in the female differs from that in the male in the perforation of all the layers in the median line by the vulvovaginal passage and the resulting necessary adaptation of the muscles. It is as if the bulbocavernosi and the bulb were cleft in two halves through their median raphé. The median cleft thus formed represents the vulva and the lower end of the vagina, while the two halves of the bulb and of the bulbocavernosi represent the bulbi vestibuli and the attenuated compressor or sphincter vaginæ respectively.

The corpora cavernosa, the ischiocavernosi, and the superficial transverse perinei muscles differ only in their smaller size. The deep transversus perinei muscle, like the two layers of the triangular ligament is of course partly cleft by the vagina.

The "**perineal body,**" *triangular* on sagittal section and *bounded* in front by the vulvovaginal wall, behind by the anterior rectal wall, and below by the cutaneous surface between the anus and the posterior vulvar commissure, is peculiar to the female. Besides the central point

Fig. 166



Frontal section of the ischiorectal space, passing through the ischial tuberosities. (Tillaux.)

of the perineum and the muscles that meet here, it contains a meshwork of connective tissue and elastic fibers, and unstriped muscle tissue. Thus it is fitted to stretch in parturition, as it does to a remarkable degree during the passage of the head. It is in this part and the posterior vulvovaginal wall that ruptures of the perineum occur during labor. Such ruptures may be superficial or they may even extend entirely through into the rectum. It is the ischiorectal regions and the portion of the perineum behind the vulva, not the firmer anterior part, that yield most in parturition, so as to allow the passage of the fetal

head. The cutaneous base of the perineal body, between the anal and vaginal orifices, is often spoken of as the "perineum." It measures 3 cm. ($1\frac{1}{4}$ in.) anteroposteriorly and extends laterally between the two ischial tuberosities.

The Anal Triangle or Ischiorectal Region.—The **superficial fascia** contains a great abundance of *fat* which fills the two pyramidal **ischiorectal fossæ**, lying one on either side of the anus (Fig. 166). These fossæ are *bounded* above and internally by the obliquely directed levator ani and coccygeus muscles (pelvic floor), lined beneath by the ischiorectal or anal fascia, and externally by the vertical obturator internus, covered by the obturator fascia. In front each fossa ends superficially at the base of the perineal ledge, but more deeply it extends forward, nearly as far as the symphysis, as the **anterior recess**. This *lies* on top of the perineal ledge, beneath the levator ani, and extends forward on either side of the prostate, between it and the ischiopubic rami laterally. Posteriorly each fossa ends superficially along the great sacrosciatic ligament, but deeply it extends backward a variable distance toward the sacrum between the ligament and the pelvic floor, as the **posterior recess**.

The **apex** of the fossa is along the white line on the obturator fascia, or a little below it, so that its *depth* is about 5 cm. (2 in.) behind, less in front. The *base measures* 2.5 cm. (1 in.) in breadth and 5 cm. (2 in.) from before backward. *Crossing this space* about its centre, from the lateral wall to the anus, are the *inferior hemorrhoidal vessels*, while the external angle is crossed by the *superficial perineal vessels and nerves* and along the posterior border runs the *fourth sacral nerve*. The presence of these nerves, especially the hemorrhoidal, explains the great *pain* which usually accompanies **ischiorectal abscess**. In *opening* an ischiorectal abscess the structures to *avoid* are the pudic and inferior hemorrhoidal vessels and the rectum. We *incise* in a line radiating from the anus, being careful not to incise too deeply near the anus, on account of the rectum, or too far toward the tuber ischii, where the pudic vessels run in a canal (Alcock's) in the obturator fascia, 2.5 to 3.7 cm. (1 to $1\frac{1}{2}$ in.) above the lower end of the tuberosity. Early incision should be practised to prevent the inflammation from extending throughout the entire fossa.

Inflammation in the ischiorectal fossa is *favored* by the poor blood supply of the contained fat and by the tendency to congestion, due to the dependent position and the lack of support of the veins, especially in patients suffering from venous congestion or feeble circulation, such as occurs in diseases of the liver (cirrhosis), heart, and lungs (phthisis). The inflammation is also favored by sitting on a cold, wet seat, by injury, and by the passage of infection through the rectal wall, preceded perhaps by an ulcer of the lower rectum. *Ischiorectal abscess bulges and tends to break* where resistance is least, *i. e.*, in the rectum, or on the skin beside the anus or along the border of the gluteus maximus. If it perforates both on the skin and in the rectum, a complete **fistula in ano** results, whose *internal opening* is usually within 12 mm. ($\frac{1}{2}$ in.) of the anus. Owing to the constant dragging apart of the walls, toward the

anus by the sphincter and from the anus by the levator ani, and the re-infection of the tract from the rectum, spontaneous cure is rare and operation is required (see also p. 416).

The pad of fat filling the ischiorectal fossa serves as an elastic cushion to the rectum and allows its descent and expansion during defecation. The anal portion of the rectum occupies the space between these two fossæ. The ischiorectal fossa is opened into in lateral lithotomy and in the lateral and the transversely curved incisions to expose the prostate, seminal vesicles, etc.

CHAPTER VI.

THE LOWER EXTREMITY.

The lower extremity is especially *adapted to bear the weight of the body* by its stronger and heavier build and the stronger and less movable connection of its first segment, the thigh. as compared with the upper extremity.

THE HIP.

The upper segment, the region of the hip, will be studied in *two sections:* (1) a posterior or gluteal region, the buttocks, and (2) an anterior region, including the hip joint.

The Posterior or Gluteal Region, the Buttocks.

This region is *bounded* above by the iliac crest, below by the gluteal fold, internally by the sacrum and coccyx, and externally by a line from the anterior superior iliac spine to the great trochanter.

Surface Markings and Landmarks.—The iliac crest and its anterior superior spine are readily felt. The *posterior superior spine* is less distinct, especially in stout subjects, in whom its position is indicated by a small depression. The **great trochanter** is a prominent landmark, especially when the thigh is adducted or rotated out. In very stout subjects a slight depression marks its position. Its upper border is made less sharply defined by the tendon of the gluteus medius which passes over it. The **ischial tuberosities** are readily felt on the borderline between the buttocks and the perineum. When the thighs are extended they are covered by the fleshy fibers of the lower borders of the glutei maximi, which rise above them when the thighs are flexed. The *sciatic notch* can only be felt in those greatly emaciated. The transverse gluteal fold, or "**fold of the buttocks,**" is neither due to nor does it correspond with the lower border of the gluteus maximus, which is lower and more oblique than the fold. The fold is *due to* a creasing of the skin in extension of the hip. *In flexion* of the hip joint the buttocks are flattened and the *fold becomes oblique* and is finally *obliterated.* Its disappearance and the flattening of the buttocks in early hip disease are useful diagnostic signs, and are due to the flexion of the hip joint, which is almost constantly present. They are not due to but precede the wasting of the gluteal muscles, which exaggerates these symptoms. The *great sacrosciatic ligament* can be felt on deep pressure beneath the

lower edge of the gluteus maximus. The *tensor fasciæ latæ* (*vaginæ femoris*) forms a slight prominence extending from a point just outside the anterior superior spine downward and somewhat backward to the iliotibial band, on the outer aspect of the thigh, 7.5 to 10 cm. (3 to 4 in.) below the great trochanter.

Topography.—The *posterior superior iliac spine* is on a level with the second sacral spine and the centre of the sacro-iliac joint. In this connection it may be noted that the *lowest limit of the spinal membranes* and the cerebrospinal fluid corresponds to the second (or third) sacral spine and the upper border of the great sacrosciatic notch. The *spine of the ischium* is on a level with the first piece of the coccyx. The level of the *upper border of the great trochanter* is about 2 cm. ($\frac{3}{4}$ in.) below the top of the femoral head, at or just below the centre of the hip joint, and nearly on a level with the pubic spine. The atrophy of the gluteus medius and minimus muscles, which fill up the hollow between the ilium and the trochanter and render the prominence of the latter comparatively slight, makes the trochanter very conspicuous.

Nelaton's line, which is drawn from the anterior superior iliac spine to the most prominent part of the tuber ischii, normally crosses the centre of the acetabulum and touches the top of the great trochanter in the extended position. Its relation to the trochanter is used in the diagnosis of fractures of the neck of the femur, dislocations of the hip and late stages of hip-joint disease, in which the trochanter is displaced upward. A still more convenient line for this purpose is **Bryant's line**, the upper line of Bryant's triangle. This line is drawn vertically backward (in the horizontal posture) from the anterior superior iliac spine, and the distance from this line to the top of the great trochanter, as compared with that on the opposite side, indicates any displacement upward of the trochanter. *Robson's line* is practically the same, and is drawn vertically from the anterior superior spine to a transverse line touching the top of the great trochanter.

Position of the Vessels and Nerves.—The *gluteal artery and the nerve* just below it, as they emerge from the pelvis, correspond about to the middle of the *superior border of the sciatic notch.* This point is indicated by the junction of the upper and middle thirds of a *line* drawn from the posterior superior iliac spine to the top of the great trochanter, when the thigh is slightly flexed and rotated inward. Incising in this line, and splitting the gluteus maximus muscle, the top of the sciatic notch is felt for and the vessel is there found, if its ligature is required. The *sciatic artery,* with the *great sciatic nerve* external to it. *emerges* from the sciatic notch at a point corresponding to the junction of the middle and lower thirds of a *line* drawn from the posterior superior iliac spine to the outer part of the tuber ischii. This line crosses the *posterior inferior iliac* spine 5 cm. (2 in.) below the upper end and the *ischial spine* 10 cm. (4 in.) below. The latter spine is crossed by the internal pudic artery as it passes from the great to the small sacrosciatic foramen.

The Great Sciatic Nerve.—The great sciatic nerve, emerging from the pelvis at the point mentioned, *passes* thence down the middle of the back of the thigh *in a line* to the middle of the popliteal space, and *crosses the line* from the tuber ischii to the outer side of the great trochanter at the junction of its middle and inner thirds. *At this point* the nerve emerges from beneath the lower border of the gluteus maximus and is *most accessible,* being covered only by the skin and fascia, before it is crossed by the long head of the biceps. It may be *exposed by an incision* having this point as its centre and running either in the line of the nerve or along the lower border of the gluteus maximus, across this line. The latter muscle is retracted upward and outward and the nerve is found as a white cord in the loose tissue separating this muscle from the hamstring muscles. This, its most superficial point, is apt to be a "tender point" in sciatica (see also page 489).

We may now study this region by layers. **The skin** is *thick, coarse,* and firmly connected with the underlying fascia, so that it is *not freely movable.* It is often the seat of furuncles, which are apt to be very painful, owing to its plentiful nerve supply.[1] **The subcutaneous tissue** contains a large amount of *fat,* to which, even more than to the development of the gluteus maximus, the buttocks owe their prominence and roundness. This tissue is a *favorite site for lipomata,* and its laxity allows large effusions of pus and blood to occur.

The Deep Fascia.—The deep fascia is *attached* to the iliac crest above, the sacrum and coccyx mesially, and splits to inclose the gluteus maximus in a sheath. The deep layer of this sheath covers the gluteus medius, over which the fascia is thicker than over the maximus, especially in front of the latter. By means of this fascia the glutei medius and minimus are enclosed in an *osseo-aponeurotic space,* which is only open below toward the thigh and internally toward the pelvis at the sciatic foramina. *Effusions* of blood or pus pent up *in this space* press upon the contained nerves and explain the severe pains associated with them. *Such abscesses* may extend into the pelvis or a pelvic abscess may extend into this space, through the sciatic foramina. Pus or blood beneath the deep fascia often travels for some distance down the thigh before it can reach the surface, and in one case, related by Farabeuf, the abscess reached the ankle before it broke. *Extravasations of blood* beneath the fascia may fluctuate and be mistaken for abscess, as they may occur without any discoloration of the skin, at least for some time, and then perhaps at some distance down the thigh. The deep or *gluteal fascia is continuous* below with the fascia lata of the thigh, and laterally with that thickened part of it known, from its attachments, as the *iliotibial band.* The latter serves as the insertion of the tensor vaginæ femoris and the anterior expanded part of the gluteus maximus tendon, both of which increase the thickness of the band. Across the gap between the iliac crest and the great trochanter this band is tightly

[1] This includes filaments of the posterior division of the lumbar and sacral nerves, the lateral cutaneous branch of the last thoracic nerve, the iliac branch of the iliohypogastric nerve, large branches of the small sciatic nerve, and filaments of the external cutaneous nerve.

stretched, so as to firmly resist the pressure of the fingers. If, however, the trochanter is raised this band is relaxed, a fact that may be useful in the diagnosis of fractures of the neck of the femur, etc.

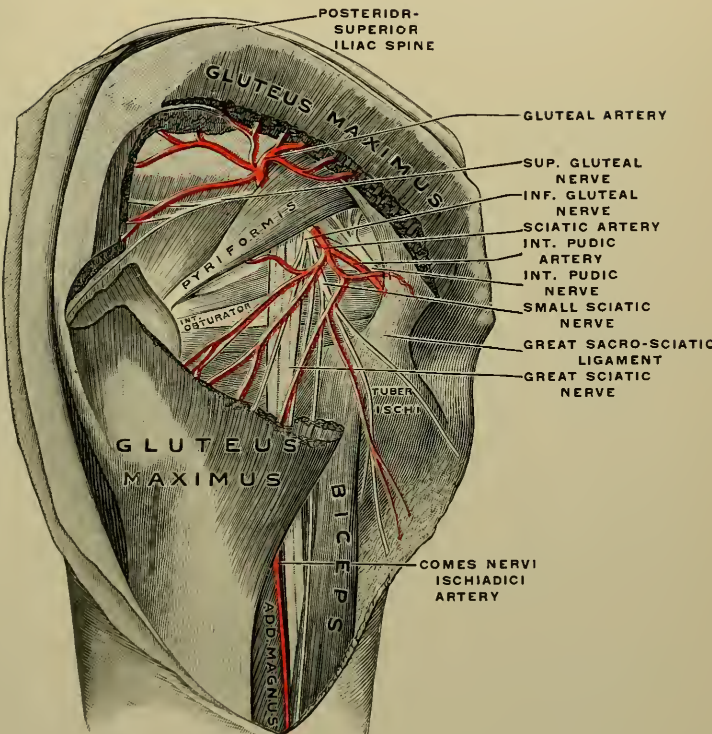
The Muscles.—The muscles of the buttocks may be divided into *three layers*, between the outer of which, consisting of the gluteus maximus, and the middle, comprising the gluteus medius, pyriformis, obturator internus and quadratus femoris, lie most of the important nerves and vessels. Most *incisions* in this region are made parallel with the fibers of the gluteus maximus, which run obliquely downward and forward. This muscle may then be split instead of cut. The *gluteus maximus* does not act to maintain the erect position, but only in rising to that position, in climbing stairs, etc., in jumping, and in carrying heavy weights on the back. Hence *when this muscle is paralyzed* the patient can walk on a level surface, but has difficulty in rising from a seat, in climbing stairs, etc. *In paralysis of the gluteus medius* there is difficulty in maintaining the erect position on the side paralyzed.

Of the **bursae** in this region, *three* at least are *over the great trochanter*, separating the latter from each of the three gluteal muscles. Only *that between the trochanter and the gluteus maximus* is of much practical importance, for it may be inflamed and render painful the movements of the thigh. Hence in the inflammation of this bursa the thigh is kept flexed and adducted, to rest or relax the gluteal muscles, whose action is to extend and abduct it. A *bursa over the tuber ischii* separates that process from the skin and subcutaneous tissues, in the sitting posture (see pp. 394 and 485). Among those whose occupation requires much sitting this bursa is often inflamed and enlarged, forming what is known, according to circumstances, as "weaver's," "coachman's," "drayman's," or "lighterman's" "bottom." When enlarged it may press upon the inferior pudendal nerve.

Vessels.—The *gluteal artery* is usually the largest of this region, being of the size of the ulnar, hence its wounds are serious and have been rapidly fatal. *Wounds* of this artery usually involve only its branches, for the portion of its trunk outside of the pelvis is not longer than 5 mm. (Bouisson). Hence in place of extrapelvic *ligature* of the vessel for aneurysm, ligation of the internal iliac artery is usually performed. *Gluteal aneurysm* is not very uncommon. To cure it, compression of the internal iliac artery, through the rectum, has been tried by Dr. Sands (*Am. Jour. Med. Sci.*, 1881), but not effectively. If the aneurysm involves the trunk of the gluteal artery, which runs, near its commencement, between the lumbosacral cord and the first sacral nerve, nerve symptoms from pressure can hardly fail to occur. The *gluteal and sciatic arteries* can be and have been *ligated* for wounds, through an incision in the buttocks over their course (see p. 486). The size of the accompanying veins and their close attachment to the artery increase the difficulty of ligation of the gluteal artery. There are several cases recorded, of which Henle collected six, where the greatly enlarged *sciatic artery,* running alongside of the sciatic nerve, *took the place of the femoral artery* to the popliteal space, in the absence of the latter vessel. The

PLATE XLVII

FIG. 167



Gluteal Region of the Left Side after Removal of the Gluteus Maximus and Part of the Gluteus Medius. (Joessel.)

sciatic artery is most important in the *collateral circulation* after ligature of the femoral.

The superficial **lymphatics** of the buttocks run to the inguinal nodes, the deep lymphatics accompany the bloodvessels to the internal iliac or hypogastric nodes after traversing some small and inconstant nodes beneath the pyriformis muscle.

The Great Sciatic Nerve.—The great sciatic nerve, after emerging from the pelvis at the point indicated above, is *covered by* the gluteus maximus and *lies upon* the obturator internus and the quadratus femoris. In spite of its close relation to the hip-joint, it is almost never injured in hip-joint dislocations. In two or three cases only it has been hooked up in front of the head of the femur. Neuralgia in this nerve is known as **sciatica**, a condition *due to* a variety of causes. *Within the pelvis* aneurysm of some of the branches of the internal iliac artery, engorgement of some of the pelvic veins lying in front of it (Erb), fecal accumulation in the rectum, the fetal head in tedious labors and various forms of pelvic tumor, usually palpable through the rectum, may cause sciatica by pressure. Pelvic or spinal tumor should be suspected in the presence of a double sciatica. *Outside of the pelvis* it is near enough to the surface to be affected by cold.

Stretching the nerve has been employed in the treatment of this condition, for excision is unjustifiable owing to its great importance. The so-called bloodless or *dry stretching* consists in forcibly flexing the hip while the knee is kept extended. But this stretches not only the nerve, but also the hamstring muscles, hence *wet stretching* is usually employed, the nerve being first exposed by an incision (see pp. 487 and 510). Trombetta found that a weight of 183 pounds was required to break the great sciatic nerve, representing a force not likely to be equalled in stretching. But the nerve can be torn away from the soft spinal cord by a force not at all sufficient to rupture the nerve, hence care must be exercised in making traction on its proximal side. A safe rule is to use only enough force to raise the limb from the table, the patient being in the prone position.

The possibility of wounding the pelvic viscera through the sciatic foramina, in wounds of the buttocks, should be remembered. Treves mentions a fatal case of peritonitis due to a stab wound of the bladder through the buttock, and the rectum has been injured in like manner. *We operate upon the pelvic viscera* through the great sacrosciatic foramen after division of the great sacrosciatic ligament, with or without removal of the coccyx and part of the sacrum. The former is the method of Kraske in resection of the rectum.

The Anterior or Subinguinal Region, the Region of Scarpa's Triangle.

This is *bounded* above by Poupart's ligament, below by a line 12 to 15 cm. (5 to 6 in.) below it, on a level with the gluteal fold.

Surface Markings and Landmarks.—The anterior superior iliac spine, the pubic spine, and Poupart's ligament are most important landmarks and readily made out (see p. 268). The *sartorius muscle* is rendered visible or palpable when the thigh is raised and adducted, the *adductor longus* when it is adducted in spite of resistance. The former runs obliquely downward and inward from the anterior superior iliac spine, the latter downward and outward from just below the pubic spine, hence it may be used as a guide to that spine in stout females. These two muscles, crossing 12 to 15 cm. (5 to 6 in.) below Poupart's ligament (10 cm. [4 in.] in muscular subjects), bound, with the latter, **Scarpa's triangle**. This triangle may appear as a slight hollow below the fold of the groin. In thin subjects the superficial *inguinal lymph nodes* can be felt near the base of the triangle; if enlarged they are readily felt. In emaciated subjects a prominence sometimes appears below the outer half of Poupart's ligament, corresponding to the *head of the femur*, which may be indistinctly felt in extension and outward rotation of the thigh.

Topography.—The *femoral ring* lies on the horizontal line connecting the pubic spine and the top of the great trochanter, 2.5 cm. (1 in.) from the former. It is also 12 mm. ($\frac{1}{2}$ in.) internal to the femoral artery just below Poupart's ligament. The *artery* is a little internal to the middle of the ligament, or midway between the anterior superior iliac spine and the symphysis. From thence the **line of the artery** is drawn to the adductor tubercle, or the back of the inner condyle, the thigh being slightly flexed and abducted. The upper two-thirds of this line corresponds to the position of the femoral artery. Its *profunda branch* is given off about 3.5 cm. ($1\frac{1}{2}$ in.) below Poupart's ligament, and the artery is covered by the sartorius about 7.5 to 10 cm. (3 to 4 in.) below the same point. The *femoral vein* bears a relation to the artery just the reverse of the sartorius muscle throughout its extent. The *saphenous opening* lies with its centre 3.5 cm. ($1\frac{1}{2}$ in.) below and also external to the pubic spine, where its position is sometimes indicated by a slight depression. In those without much subcutaneous fat the *long saphenous vein* can be seen or felt running up to the saphenous opening. This vein penetrates the cribriform fascia to join the femoral vein 3 to 4 cm. ($1\frac{1}{5}$ to $1\frac{3}{5}$ in.) below Poupart's ligament. Just below its passage through the fascia it sometimes presents a dilatation which might even be mistaken for a femoral hernia. This vein and its tributaries are often the seat of varices, commonly the result of congenital conditions. Trendelenburg's operation for varicose veins of the leg consists of the double ligature and division of this vein just below its upper end.

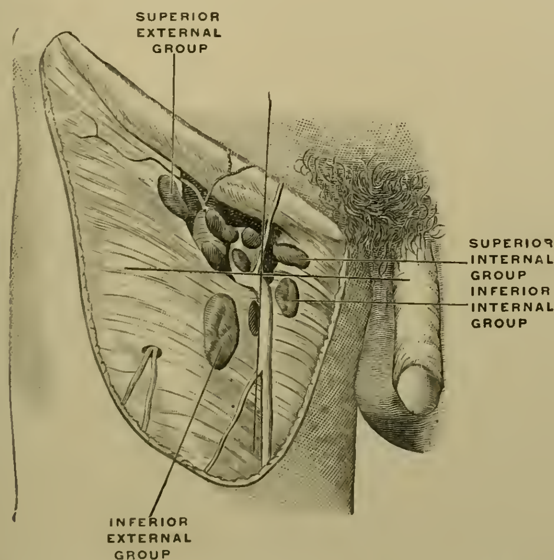
The Skin.—The skin is *thin* and, below Poupart's ligament, very *movable* on account of its loose attachment. *Incisions* parallel with Poupart's ligament do not gape, hence in opening abscesses here a vertical incision affords better drainage by reason of the resulting separation of the edges. *After burns* and other loss of substance of the skin of this region, the resulting cicatrix may cause flexion of the hip by *cicatricial contraction*. *Supernumerary mammary glands* are sometimes found in

this region, and Treves refers to a case, related by Jessieu, of a woman who nursed her child from a breast so placed.

The Superficial Fascia.—The superficial fascia is usually described in *two layers,* of which the superficial one contains the subcutaneous fat, which may be so thick as to make operations here more difficult. This region is a *favorite situation for fatty tumors* in the superficial fascia, which here show a tendency to travel in the direction of gravity, owing to the looseness of the tissue and of the attachment of the capsule of the tumor.

Between the two layers are the **superficial inguinal nodes.** They may be conventionally divided into four groups, by a vertical and a horizontal line drawn through the point where the long saphenous vein

Fig. 168



Superficial inguinal glands. Cribriform fascia has been removed so as to expose the femoral vessels. (Poirier and Charpy.)

pierces the cribriform fascia. The upper two groups correspond more or less with the convenient subdivision, the *horizontal group,* lying just below and parallel with Poupart's ligament, the lower two groups with the *vertical group,* parallel with and along the long saphenous vein. The vertical group receives lymphatics from the surface of the lower extremity, the perineum, and some from the external genitals and the inner part of the buttocks. The horizontal nodes from without inward receive the lymphatics of the outer part of the buttocks, the lower abdomen, the external genitals, and the inner part of the buttocks. Although this is true in a general way, yet no nodes constantly receive a definite set of lymphatics, and all the nodes are connected in a plexiform manner. However, when these glands are enlarged or are the seat of abscess, as

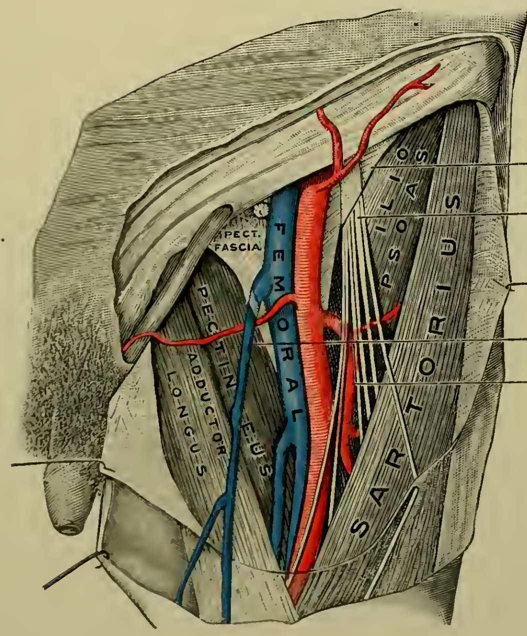
often occurs, we should look to the parts named for the primary lesion. The efferents of the superficial nodes pass to the deep inguinal and iliac nodes.

The **cribriform fascia** is variously described. English and American authors, for the most part, consider it as belonging to the deep *layer of the superficial fascia* and as covering an oval area which is supposed to intervene between the anterior or iliac portion and the deeper or pectineal portion of the fascia lata. German and French authors consider it as a *part of the deep fascia* (fascia lata) which divides below Poupart's ligament into two triangular layers, one of which passes in front and the other behind the femoral vessels to unite together externally in front of the iliopsoas, internally in front of the pectineus and below around the sheath of the vessels, 3 to 4 cm. ($1\frac{1}{5}$ to $1\frac{3}{5}$ in.) below Poupart's ligament. In either case the cribriform fascia refers to the fascia covering an oval area, the *fossa ovalis* or *saphenous opening*, measuring 2.5 cm. (1 in.) in its long or vertical diameter. This fascia is thin and perforated by superficial bloodvessels, lymphatic vessels passing from the superficial to the deep nodes, and, at its lower end, by the long saphenous vein as it passes back to empty into the femoral vein. The perforations give rise to the name cribriform (sieve-like) fascia. It lies immediately in front of the lower end of the femoral canal, forms one of the coverings of a femoral hernia, offers little resistance to the passage of pus, and on it lie some of the superficial lymph nodes. The femoral canal and the vascular and muscular compartments have been already referred to (see pp. 302–3). The density of the **deep fascia (fascia lata)** affects the extension of underlying growths and abscesses and the opening of the latter. If a psoas abscess breaks through the sheath of the iliopsoas muscle below Poupart's ligament, it may travel in the line of gravity far down the thigh before it opens on the surface. The firmness of this fascia also modifies the surface appearance and feel of underlying growths.

Within Scarpa's triangle, and at a deeper level, is a *second triangle* or a groove between the iliopsoas and the pectineus (*fossa iliopectinea*), in which lie the femoral vessels. The iliopsoas and an underlying layer of fatty and areolar tissue intervenes between the vessels and the hip joint so that in amputation at or excision of the hip joint the vessels are protected from injury in freeing the head of the bone. Between the iliopsoas muscle and the thinnest part of the capsule of the hip is a **bursa** which may communicate with the joint. This "psoas bursa" may form a large visible tumor below the middle of Poupart's ligament, when chronically inflamed. Inflammation of this bursa may extend to the hip joint, or vice versa. It causes flexion of the thigh, to relieve the pressure of the muscle on the bursa and on account of reflex irritation of the iliopsoas. *Sprain* or even partial rupture of one or more *of the adductor group of muscles,* especially the adductor longus, often occurs in horseback exercise. The lesion is usually close to their pelvic attachments. It may be accompanied by much effusion of blood, and may sometimes be followed by the ossification of the tendon of the adductor

PLATE XLVIII

FIG. 169



Region of Scarpa's Triangle, left side. (Joessel.)

longus or magnus, to the extent of 1 to 7.5 cm. ($\frac{1}{2}$ to 3 in.), a condition known as *"rider's bone,"* and seen most often in cavalrymen.

Vessels.—The **femoral artery** bisects Scarpa's triangle from its base to its apex. The line of its course has already been given. *Where it crosses the pelvic margin,* just below Poupart's ligament and $3\frac{1}{2}$ cm. ($1\frac{1}{3}$ in.) external to the pubic spine (Richet), it is only separated from the iliopectineal eminence by a thin layer of the iliopsoas. Hence *compression* of the artery, which has often been successful in popliteal aneurysm, is here most easily made by pressure backward. A *little lower* it lies in front of the head of the femur, from which it is separated by a thicker layer of the iliopsoas. *Still lower* it lies in front of and internal to the neck of the femur and the hip capsule. *In applying pressure* to the artery we should avoid pressure on the vein internal to it, because of the possible danger of phlebitis. The *anterior crural nerve* is separated from the artery by the iliac fascia, so that, although it lies only 6 mm. ($\frac{1}{4}$ in.) external to it, just below Poupart's ligament, it is not in much danger of injury by pressure in compression of the artery.

The length of the common femoral artery, or that part above the profunda, may practically be taken to be the distance between the origins of the deep epigastric and of the profunda femoris branches. Although this is about 4 cm. ($1\frac{3}{5}$ in.) in the majority of cases, Vignerie found that in about 16 per cent. the distance was 2 cm. ($\frac{4}{5}$ in.) or less. The common femoral may, therefore, be so short as to render its ligature difficult. Before the days of antisepsis and asepsis the nearness of a large collateral branch was most important in the ligature of large arteries, on account of the danger of secondary hemorrhage if the wound became infected, so that it was advised to tie the external iliac instead of the common femoral, when ligature of the latter was indicated. Nowadays a long clot, or indeed any clot, between the point of ligature and the nearest large branch is not considered necessary, so that this objection to tying the common femoral no longer holds good. However, the *femoral* is *commonly ligated at the apex of Scarpa's triangle,* unless ligature at this point is contra-indicated. *Here* the sartorius crossing it serves as a guide, the vein is behind and somewhat adherent, the saphenous vein is internal, and the long saphenous nerve is external. The femoral artery, from its superficial position in Scarpa's triangle, is *liable to be wounded.* **Aneurysm** is relatively *common in the common femoral,* for the artery is affected by the movements of the hip, is exposed to injury from its superficial position, and it bifurcates into two large trunks. Arteriovenous aneurysms from wounds may also occur here.

As the *tributaries of the common femoral vein,* or that portion of the femoral vein above the entrance of the long saphenous vein, are provided with valves which should normally prevent the backward flow from the femoral through its tributaries to the tributaries of the pelvic veins anastomosing with them, it would appear as if the femoral vein was the only outlet to the pelvis of the blood of the lower extremity. From this premise it was argued that the ligature of the common femoral vein alone would lead to gangrene, and should not be done without

simultaneous ligature of the artery, to prevent the inflow of too much blood into the limb. In fact, formerly many ligated the artery only in case of a wound of the vein. But many cases of isolated ligature of the common femoral vein are on record without gangrene resulting. In fact, Braun found from statistics that the ligature of the common femoral vein alone was less often followed by gangrene of the extremity than either ligature of the artery alone or of both artery and vein. Experimentally Braun found that in 85 per cent. the valves of the tributaries gave way before a pressure of 180 mm. of mercury. The greater the pressure the better the chance of venous collateral circulation, hence the artery should not be ligated, unless necessary, in order to increase the pressure in the veins. According to Richet and Verneuil the collateral circulation occurs especially between the external pudic veins and the veins of the pelvis and between the internal circumflex veins and the veins of the buttocks. It is quite probable that there are more collateral anastomoses than are known, and that the valves are often wanting or insufficient. In wounds of this vein lateral ligature has been successful in a number of cases and should be employed when possible.

Thrombophlebitis involves the femoral vein not infrequently as a sequela of typhoid and other fevers, as well as of operations like appendectomy, hysterectomy, etc., even when they are apparently aseptic. The cause is probably a slight degree of infection, a sluggish circulation, the dependent position of the part in bed, and in fevers the altered constitution of the blood; and the result is pain, usually followed by edema of the leg.

The **deep lymphatic nodes**, one to three in number, *lie* in front of and internal to the femoral vein, and receive the deep lymphatics of the lower extremity. The upper one, the node of Cloquet (or Rosenmüller), lies upon the septum crurale (see p. 304), and really belongs to the iliac nodes. The pathology of **elephantiasis**, which is more common in the lower extremity than elsewhere, is concerned with the lymphatics of this region which are obstructed by the filaria sanguinis hominis, a small thread-worm. This obstruction leads to an enormous increase in size of the extremity from distention of the lymph channels and hypertrophy of the connective tissue.

The *crural branch of the genitocrural nerve* gives sensory filaments to the skin over Scarpa's triangle, the irritation of which causes the "**cremasteric reflex**," which consists of the retraction of the testis, and is due to the contraction of the cremaster muscle, which is supplied by the genital branch of this nerve. This reflex is most marked in children and young adults, and indicates the condition of the second lumbar segment of the cord, which is the spinal centre of this nerve.

THE HIP JOINT.

Topography.—*The centre of the acetabulum lies* in Nélaton's line, on or just above the level of the top of the great trochanter and a little below the horizontal level of the upper border of the symphysis. The tuber

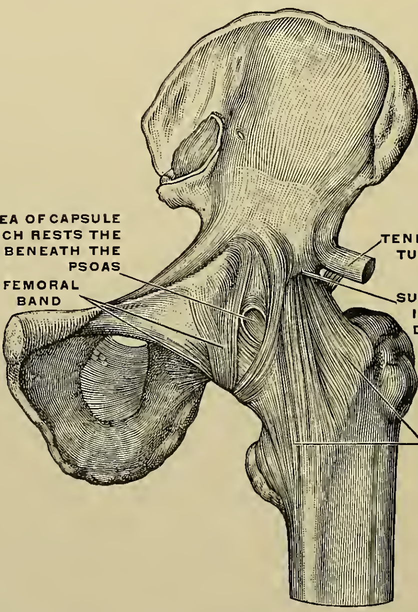
ischii lies below and behind it. The *centre of the head of the femur* lies about 5 cm. (2 in.) directly below the anterior inferior iliac spine, and on a line drawn at right angles to the centre of the line connecting the anterior superior iliac spine and the spine of the pubis, about 5 cm. (2 in.) from the latter line. At this point it may sometimes be *felt* in emaciated subjects. The *top of the head of the femur* is 18 mm. ($\frac{3}{4}$ in.) above the upper border of the great trochanter. The portion of the *great trochanter* which is most external and subcutaneous is about 2.5 cm. (1 in.) below its upper margin. According to Hueter the top of the great trochanter is relatively higher in the child, owing to the relative shortness of the neck.

The cartilage-covered portion of the *femoral head* is somewhat more than a hemisphere, and has a radius of about 2.5 cm. (1 in.). The superior and anterior aspects of the head are rather more covered by cartilage than the inferior and posterior. The depression for the ligamentum teres, behind and below the centre of the head, is a little below the point reached by the prolongation of the axis of the neck. The articular or cartilage-covered surface of the *acetabulum* is horseshoe-shaped, 12 to 25 mm. ($\frac{1}{2}$ to 1 in.) in width, and encloses a thin, non-articular area of bone. The latter area is seldom fractured, for, in spite of its thinness, it does not receive the direct impact of the femoral head, on account of the shape of the cavity. According to Tillaux, one of the chief functions of the *ligamentum teres*, as indicated by its oblique direction upward and *inward* from the acetabulum to the head of the femur, is to arrest the pressure of the head against the bottom of the acetabulum. In rare cases suppuration in the hip joint may reach the pelvis, or vice versa, by perforating this thin area. Before the eighteenth year, when the *Y-shaped cartilage* uniting the three bones which meet in the acetabulum ossifies, perforation may occur through the cartilage and the acetabulum may be broken up into its three parts by disease or injury. The bone just above the acetabulum is very thick to transmit the weight of the trunk to the head of the femur (see p. 397). The acetabulum measures 3 to 3.5 cm. ($1\frac{1}{4}$ to $1\frac{1}{2}$ in.) in depth in the male, somewhat less in the female, and it averages 5 cm. (2 in.) in diameter at its rim.

The strength of the hip joint depends not only upon the shape of the bones, but also on the strength of the thickenings of the capsule and of the surrounding muscles and tendons. The strongest part of the capsule is the **iliofemoral band or Y ligament**, which is 6 mm. ($\frac{1}{4}$ in.) thick in its thickest part, and is one of the strongest ligaments of the body, being capable of sustaining a strain of from 250 to 750 pounds (Bigelow). This ligament is *of the utmost importance in dislocations* of the hip joint in determining both the position of the limb and the mechanism of reduction by manipulation, and it is almost never torn. The thinnest and *weakest parts of the capsule* are on either side of the pubofemoral band. The *thin part in front* of and external to it is just below and external to the iliopubic eminence, between the pubo- and iliofemoral bands, and *under the bursa* between the iliopsoas muscle and the joint

capsule. There is often a defect in this thin area, so that the bursa and the joint are only separated by synovial membrane, and the latter is also sometimes wanting, making a direct communication between the two. This explains how pus in the joint can readily perforate or extend into the bursa and so come to lie beneath the iliopsoas, and also how a psoas abscess may occasionally invade the joint. The *thin area behind* and internal to the pubofemoral band is at the lower end of the postero-internal part of the capsule. The *rupture of the capsule* in dislocation of the hip *occurs most commonly in this area.* When the joint is distended with effusion the *swelling* naturally *first appears at these two thin areas,* which are accessible to palpation and correspond to the most marked

Fig. 170



Ligaments of the hip joint of the left side. Anterior view. (Joessel.)

and earliest tenderness and swelling. In general the outer (upper) and anterior parts of the capsule are thick and strong, the inner (lower) and posterior parts thin and weak. The pressure on and tension of the capsule are greatest near its pelvic attachment where the head impinges upon it most.

The **cotyloid ligament** closely embraces the head of the femur external to its greatest diameter, and, by preventing the entrance of air, *holds the head in place by atmospheric pressure,* when the capsule and the surrounding muscles are divided. Hence in excision or amputation of the hip joint this ligament is divided to permit the removal of the head from the socket. Opening an abscess connected with the hip joint does not increase the risk of pathological dislocation, unless the abscess

also communicates with the space between the head and the socket and has destroyed the continuity of the cotyloid ligament or has eroded the head embraced by it. The cotyloid ligament *levels over* the slight depressions of the margin of the acetabulum, where the pubis joins the ilium and the latter the ischium. Hence these slight depressions can have no influence upon the mechanism of dislocation, as supposed by Malgaigne.

No definite *function* is agreed upon for the *ligamentum teres*. According to Hyrtl, the vessels which it was supposed to carry to the head of the femur do not reach the latter, but bend around into the efferent veins. In childhood they may reach and nourish the head, and this may be its chief function. Although put on the stretch by flexion combined with adduction or outward rotation, these movements are limited by other and stronger ligaments (vide infra). In operations it must first be cut before the head can be removed from the socket. Unless abnormally long, it is always *torn in dislocations*, except in the congenital variety, in which it is lengthened, even to 6 or 8 cm. ($2\frac{1}{2}$ to $3\frac{1}{4}$ in.).

Owing to the *direction of the neck* of the femur the two most important movements of the hip, *flexion and extension*, are accompanied by a rotation of the head in the socket without its projecting far from the latter and thus pressing unequally upon the capsule. Hence the hip joint is very secure in these two principal movements. In the other movements the head projects from the socket on the side opposite that toward which the movement takes place. As one of the factors leading to *rupture of the capsule* is the pressure of a projecting portion of the head against a weak part of the tense capsule, *dislocation is not likely to occur* during simple flexion, although the thin posterior part of the capsule is then tense, but in flexion combined with adduction, abduction, or rotation. In rotation the head projects from the socket, for the axis of rotation does not coincide with that of the neck, but is assumed to pass through the head and the intercondylar notch.

The movements of the hip joint are limited as follows: Extension by the iliofemoral band; flexion by contact of the soft parts in the groin when the knee is bent, and by the hamstring muscles when the knee is extended; abduction by the pubofemoral band; adduction by the outer part of the iliofemoral band and capsule; rotation outward by the iliofemoral band (its inner part during extension, its outer part during flexion); rotation inward by the ischiofemoral band, and in addition by the iliofemoral band, during extension.

The *hip joint*, owing to its deep position and thick covering of soft parts, is *not very liable to* attacks of *acute inflammation* from injury, exposure, etc., to which other joints are liable. It seems, however, particularly *susceptible to chronic inflammation*. Thus it is a favorite site for senile *rheumatoid arthritis*, in which the cartilages and bony surfaces are eroded, the latter eburnated, and osteophytic processes developed around the joint surfaces, so as to impede its movements.

"Hip Disease" or Coxitis.—Still more common and important is the occurrence of tuberculous inflammation of the joint known as hip

disease or coxitis. It usually begins in the upper epiphysis or the synovial membrane. Its frequency and gravity are partly accounted for by (1) the exposure of the joint to strains and injury on account of its function in carrying the weight of the body and in locomotion; (2) the intracapsular pressure, which is easily set up after the disease has begun, is readily increased on account of the firmness of the capsule and the strength of the surrounding muscles; (3) the intracapsular position of the upper epiphysis. In the great majority of cases it commences in early childhood. In this condition there is swelling and tenderness, first and most easily demonstrable beneath the middle of Poupart's ligament and behind the trochanter, corresponding to the thinnest parts of the capsule (pp. 495–6), and *the limb assumes* certain *characteristic positions* at various stages.

In the **first stage** the thigh is *flexed, abducted, and slightly everted.* This is the *position of greatest ease,* and is that assumed by the limb when fluid is forcibly injected into the joint, as in it the joint holds the most fluid. Hence it depends upon the effusion and the fact that the capsule is still intact, and is *assumed to diminish the tension* and thereby relieve the pain. This is borne out by the fact that, in cases where the primary lesion is within the bone and there is no effusion at first into the joint, this first position of flexion, abduction, and eversion is not observed, but the limb becomes at once adducted and rotated in. The position in the first stage relaxes the strongest part of the capsule, the Y ligament, the iliotibial band, and the iliopsoas muscle. *According to some* this position, as well as that assumed later on, is *due to the reflex contraction* of muscles which are supplied by branches of the same nerves that supply the joint, *i. e.,* anterior crural, obturator, and branches of the sacral plexus.

The *flexed thigh* is *made to appear straight by lordosis,* or the extension of the lumbar spine, which tilts backward the pelvis and therewith the femur without any movement in the sensitive diseased joint. By flexing the sound thigh the patient can then stand or lie with both limbs in the same coronal plane. *The lordosis can be detected* by moving the affected thigh when the patient lies on a table. When the thigh is flexed to the angle at which it is fixed (in flexion) the lordosis disappears; in other words, when the lordosis is made to disappear the degree of flexion is shown. If we continue to flex the thigh the spine becomes still more straightened, so as to squeeze the hand paced between it and the table. When the thigh is again extended the lordosis can be felt to return.

To overcome the abduction and to restore the parallelism of the limbs, without movement in the diseased and painful joint, *the pelvis is tilted* down on the diseased side and up on the sound side, which causes a lateral curvature of the lumbar spine with its concavity on the sound side. This would abduct the sound limb, which is corrected by its being adducted. Owing to the tilting of the pelvis the *diseased side* is lowered and *appears lengthened,* the sound side appears shortened (Fig. 137). If the tilting of the pelvis be corrected, the limb on the side of the disease is found abducted, the sound limb adducted. Hence on measurement

from the anterior superior iliac spine (see p. 402) we get measured shortening on the diseased side, though at this stage there is no difference in length. The measured shortening is also increased by the flexion. Thus we get apparent lengthening, measured shortening, and real equality of the limb on the affected side as compared with the opposite side. This is, then, the *stage of apparent lengthening.* The tilting of the pelvis backward and downward not only restores the parallelism of the limbs, but reduces the strain on the muscles and ligaments which hold the affected limb in its abnormal position. Muscular wasting is usually an early symptom, due at first to a reflex atrophy, from the association of the nerves of the joint and of the muscles, and later due to disuse. The thigh and gluteal muscles are most affected; the atrophy of the latter exaggerates the obliteration of the gluteal fold.

Second Stage.—After a variable time the capsule becomes softened, so that the tension is diminished and *the thigh becomes adducted and rotated inward,* still remaining *flexed.* This is probably *due to reflex muscular contraction.* The adductor muscles are supplied by one of the principal nerves (obturator) that supply the hip joint, but the inversion is perhaps less easily accounted for.

Again in this position, *to conceal the adduction* and to restore the parallelism of the limbs, *the pelvis is tilted* up on the affected side and the opposite thigh is abducted, causing a lateral curvature of the lumbar spine with its concavity on the diseased side. Hence there is apparent shortening and measured lengthening (in adduction) on the sound side. The *actual length* of the limb may or may not be affected, but if the disease progresses the limb is shortened by the absorption of the head of the bone, or by its *dislocation* onto the dorsum ilii. This dislocation is favored by the erosion of the upper and posterior margin of the acetabulum, and the softening of the capsule. This, then, is the *stage of apparent shortening* and later, perhaps, of real shortening.

On account of the deep position of the hip joint, pus found in the course of hip disease does not soon reach the surface, but, remaining pent up, it is apt to burrow in various directions and become very destructive in its results. Intra-articular abscess may work forward through the thin part of the capsule to a point beneath the tensor vaginæ femoris, or backward through the thin part of the capsule, beneath the gluteal muscles, to a point behind the trochanter, or through the cotyloid notch to the region of Scarpa's triangle, or through the acetabulum into the pelvis. The *epiphysis* that forms the head is wholly *within the joint,* and the *conjugal cartilage* that unites it with the diaphysis, and ossifies about the nineteenth year, is usually involved when the primary lesion is in the bone. This may cause a separation of the epiphysis, or it may arrest the growth of the bone at this end and thus lead to a shortening of the limb, unless compensated by increased growth at the lower end, where the principal increase in length occurs.

The well-known fact that patients with hip disease often complain of *pain in the knee,* in excess of or to the exclusion of pain in the hip, is readily explained as *a reflex.* Thus both hip joint and knee joint are

supplied by filaments from the obturator, anterior crural, and sciatic nerves, and the irritation of the hip-joint filaments is referred to those of the knee.

Dislocation of the Hip.—The comparative *rarity* of this injury is due to the great strength of the joint. In spite of the tremendous leverage of the long femur, it forms less than 2 per cent. of all dislocations. A considerable proportion (nearly 50 per cent., Prahl) occur before the age of twenty. The traumatic dislocations may be practically divided into (1) **the backward**, including (*a*) the ischiatic and (*b*) that onto the dorsum ilii, and (2) **the forward or inward**, including (*a*) the obturator and (*b*) the iliopectineal and pubic. The *backward dislocations* are by far *the most common.* The *prerequisites for a dislocation* are rupture of the capsule, almost always of the ligamentum teres, and, to a less extent, of the cotyloid ligament. Naturally the *thinner and weaker parts of the capsule* are those generally *torn;* the iliofemoral band is almost never torn, a fact of the utmost importance, which is due to its strength and the fact that it is relaxed when the luxation is produced. The *position of the limb* in which (backward) dislocation most often occurs is that of flexion, adduction, and inward rotation. In this position the head of the bone presses upon the thin postero-inferior part of the capsule. When violence is received in this position, approximating the knee and the pelvis, as in a fall from a height or the fall of a heavy object upon the back, this part of the capsule tears and allows the head to be dislocated downward over the lower and least prominent portion of the cotyloid rim. The *primary displacement* is therefore downward. The *secondary displacement* is such as may be allowed by the intact portion of the capsule, and especially the iliofemoral band, which is now rendered tense. The attachment of the latter ligament to the femur forms a *new centre of motion,* or the fulcrum of a lever of which the head and neck are the short arm and the rest of the femur the long arm. The capsule is either primarily torn at different parts in the different varieties or secondarily torn in different directions from the primary tear, to allow the different forms to occur from a primary downward displacement. Thus in obturator dislocations the capsule is torn on the inner and lower side, in the iliopectineal form antero-internally, while the everted dorsal dislocation depends upon a tear of the outer branch of the Y ligament.

If the thigh be partly lowered (extended), while the adduction and inward rotation remain unchanged, the head glides up behind the acetabulum to a dorsal or backward position. If, on the other hand, the thigh is abducted or rotated out as it is lowered, the head and neck, moving on the new centre of motion, are forced in the opposite direction to the shaft and are displaced inward and forward. This is exemplified in the reduction of dislocations. When there is a backward dislocation the head of the bone is brought below the acetabulum by increasing the flexion, and it may readily be converted into an inward dislocation by too much abduction or outward rotation, especially if upward (forward) traction on the thigh is omitted. In the reduction of an obturator

dislocation Bigelow gives preference to converting it into the dorsal form by the reverse of the above process.

Dorsal or Backward Dislocations.—In dorsal or backward dislocations the *head* of the bone *lies* behind or behind and above the centre of the acetabulum, either just behind the latter and in front of the spine of the ischium, (*a*) **ischiatic form**, or higher up on the ilium, (*b*) **dislocation onto the dorsum ilii**, as high up as in front of, but seldom above, the apex of the great sciatic notch. In the recumbent position the latter lies directly behind the anterior superior iliac spine. The *head* can be obscurely *felt* in the buttocks, above the tuber ischii, beneath the gluteus maximus. The *great trochanter* is rotated forward and approaches nearer the iliac crest than normally. It lies from 2 to 3 cm. ($\frac{3}{4}$ to $1\frac{1}{4}$ in.), above Nélaton's line in the ischiatic form, and from 3 to 7 cm. ($1\frac{1}{4}$ to $2\frac{3}{4}$ in.) in the iliac form. The *real shortening* varies within these limits; the *measured shortening* is increased by the flexion present, but may be decreased or even wholly lacking by reason of the adduction; the *apparent shortening* is increased by the flexion and adduction. The head may pass above or below the obturator internus tendon. Although Bigelow classed all cases in which the head was below the tendon as ischiatic and all above as iliac, many if not most of those called iliac pass below and beneath the tendon. The flexion and inversion are greater when the head lies below the obturator tendon. The higher up the head rests, the farther up on the postero-external aspect is the capsule torn. Usually the quadratus femoris and sometimes the obturator internus and even the pyriformis tendons are torn. The *limb is held* somewhat flexed, adducted and rotated in. This position can be readily exaggerated, but the attempt to give it the opposite position is resisted. The tension of the iliofemoral band and of the iliopsoas muscle and the position of the head and neck, which must accommodate themselves to the plane on which they lie, are largely responsible for the position assumed and the resistance to movement in the opposite direction. The normal depression behind the trochanter is lost and the depressibility of the soft parts below the outer half of Poupart's ligament, where the head normally lies, is increased.

Inward or Forward Dislocations.—If after the primary displacement the thigh is abducted *the head* of the bone may *pass* inward and forward from below the acetabulum, along its inner edge, until it reaches the thyroid foramen, (*a*) **thyroid form**, or, if the limb is further extended and everted, it may pass forward and come to lie upon or near the iliopubic eminence, (*b*) **iliopectineal form**, or, more rarely, nearer the symphysis, (*c*) **pubic form.** While this mode of production may occur in a number of cases, the *obturator* form is most often due to violence received on the back of the hip while the limb is flexed and abducted, and the *iliopectineal* form to hyperextension while the limb is everted. In both forms the head can be distinguished by touch or even by sight in its new position, especially in the pubic variety. In the latter varieties the *femoral artery* can be felt pulsating directly over it, to its inner or its outer side (pubic form). The *great trochanter* is displaced inward toward the

acetabulum, over which it may be felt. The outer and posterior portions of the hip are flattened. Both the obturator and anterior crural nerves have suffered from pressure. The *posture of the limb* varies. *In the thyroid variety* it is flexed, abducted, and usually rotated out. There is *apparent lengthening* by reason of the tilting of the pelvis, to bring the abducted limb into line. The *measurement* may show lengthening on account of the downward position of the head, in spite of the shortening due to abduction. In some cases the head has passed over the ramus into the perineum (perineal form). *In the iliopectineal variety* the limb is but little if at all abducted, markedly everted, and but little if at all flexed. In this form the apparent lengthening of the thyroid form may be wanting, if there is no abduction, and there is measured and actual *shortening*. From its position (eversion) and the presence of shortening it *may be mistaken for fracture of the neck* of the femur, but it can be distinguished from it by the presence of the head in its new position, the depression and inward displacement of the trochanter, and the marked flattening of the outer aspect of the hip. In the *pubic form* the thigh is abducted, everted, and flexed, and the vessels lie externally.

In the reduction of dislocations of the hip we may lay down the *general rule* that the head should be made to take, in the reverse direction, the route it took in becoming dislocated. The *chief obstacle* to reduction is the tension of the Y ligament in the partly extended position, and to overcome this the thigh is first flexed. This flexion also brings the head down to the lower part of the socket, where it escaped. As a general rule we may direct to first (1) **increase the deformity and then** (2) **make the opposite movements with forward traction.** (1) Relaxes the Y ligament, releases the head and brings it below the socket, while (2) forces the head through the tear in the capsule into the acetabulum. It is virtually a circumduction with forward traction. *In the dorsal form* increasing at first the adduction and inversion lifts the head of the femur away from the pelvis and the projecting rim of the acetabulum. Unless we make forward traction, after flexing and otherwise increasing the deformity, a backward dislocation is likely to be converted into a forward one, and vice versa by the "opposite movements." In other words, the *reduction* is to be made *largely by traction* rather than by manipulation. The spasmodic contraction of the muscles opposes this forward traction, hence the value of anesthesia. *Stimson's method,* in backward dislocations, of placing the patient on the face with the flexed thigh hanging over the end of the table enables us to dispense with anesthesia, as a rule; for the weight of the limb, tiring out and overcoming the contraction of the muscles, serves instead of traction, so that a slight rocking of the flexed limb accomplishes the reduction. The *obturator form* may be *reduced* by first converting it into the backward form by increasing the deformity and then making the opposite movements without traction. The *obturator form* may also be reduced by increasing the deformity and then making the opposite movements with traction forward, avoiding too free inward rotation, for fear of producing a backward dislocation; or it may be reduced by flexion, traction, and

outward rotation (Kocher). The *iliopectineal form* is best reduced by flexion, traction, and inward rotation. The rule to increase the deformity, *i. e.*, the extension, etc., should not be followed here. It may be convenient to remember that the *internal condyle* looks nearly in the same direction as the head of the femur.

Congenital Dislocations of the Hip.—The hip on one or both sides may be congenitally dislocated from lack of development of the acetabulum, especially its upper or iliac portion. In congenital dislocations the capsule is stretched and thickened, the neck is short, and the head is flat and rests on the dorsum of the ilium, when the child walks. If reduced, there is nothing to keep it from slipping out again. The trochanters can be seen beneath the glutei, above Nélaton's line, and there is usually lordosis of the lumbar spine to compensate for the backward displacement of the centre of gravity. When long displaced the muscles become shortened so that the head cannot be reduced without dividing or stretching them. A new socket may form on the ilium from osteophytic outgrowths. The ligamentum teres is usually stretched and not torn.

Fractures of the Neck of the Femur.—The *long axis* of the neck measures 3.5 to 4 cm. ($1\frac{2}{5}$ to $1\frac{3}{5}$ in.), its vertical diameter averages 36 mm. ($1\frac{1}{2}$ in.), its anteroposterior 25 mm. (1 in.) The latter diameter is much less than that of the great trochanter, and these two parts are so joined that a considerable part of the trochanter extends behind the posterior surface of the neck. In falls on the feet the neck transmits the weight of the body in such a manner as to receive a cross-strain, favoring fracture, on account of the *angle* which it forms with the shaft, averaging 125 degrees in the adult. This angle is greater in the infant, but does not decrease after adult life is reached. Hence the theory that the frequency of fractures of the neck of the femur in old age depends upon a decrease of this angle to one nearer a right angle, a position that would favor fracture, is not sustained by facts and has been abandoned. Nor is the angle sufficiently less or the trochanter enough more prominent in those of small stature and in the average female to account for the more frequent occurrence of this injury in that sex (two and a half times more frequent than in men, over fifty).

The fact remains, however, that this fracture is *essentially a lesion of old age,* is more common in women than in men, and is *often the result of slight causes,* a stumble, a misstep, or a slight fall. These facts indicate the existence of *senile changes as a predisposing cause,* and it is found that all parts of the bone are much rarefied and the cortical substance is much thinner in the aged. These changes begin and advance most quickly in the femoral neck (Humphry). This *osteoporosis affects* the cortex of the under and forepart of the neck, in the line of greatest pressure, and also two plates of compact bone which strengthen the neck, (1) the *calcar femorale,* a nearly vertical plate projecting into the spongy substance, toward the great trochanter, from a little in front of the small trochanter, and (2) *a thin dense plate,* continuous with the posterior surface of the neck, which extends

in the spongy tissue toward the outer surface of the shaft and of the trochanter.

As the *capsule is attached* in front to the base of the neck (the intertrochanteric line) and behind 12 mm. ($\frac{1}{2}$ in.) or more internal to the posterior intertrochanteric line, it follows that there can be *no strictly extracapsular fractures* of the neck, for the latter is entirely intracapsular in front. A more scientific *classification* of these fractures than that into intracapsular and extracapsular is the division into (*a*) fractures through the neck and (*b*) fractures at the base of the neck.

(*a*) **Fractures through the Neck.**—Fractures through the neck may occur at any point between the junction of the head and neck and the base of the latter, though they are said to be *more common near the head.* It is this variety especially that occurs from slight violence in the aged. As a rule, there is *angular displacement* at the fracture, from the crushing of the bone or the penetration of one fragment into the other posteriorly and inferiorly, so that the neck is bent at an angle directed upward and forward. This causes eversion and adduction of the thigh, elevation of the trochanter, and decrease of the angle of the neck. If the fracture is near the head the latter may be penetrated by the smaller and more compact neck, but true impaction is rare. The thick *periosteum* is usually *untorn* over a portion of the circumference of the neck, especially along its upper part, where it is very vascular. The periosteum is reinforced by fibers reflected from the femoral attachment of the capsule toward the head in three bands or retinacula, one behind and one at either end of the anterior intertrochanteric line. The *untorn portion* of the periosteum not only holds the fragments together, but *furnishes a source of blood supply* to the smaller fragment, to assist in the process of repair. The only other source of blood supply of the head, after fracture, is the ligamentum teres. Movements that may tear the untorn portion of the periosteum are to be carefully avoided in diagnosis and treatment. Hence crepitus should not be sought for by rotation or longitudinal movements.

(*b*) **Fractures at the Base of the Neck.**—Fractures at the base of the neck usually *follow* the line of junction of the neck and shaft quite closely, but other lines of fracture traverse the great trochanter, as a rule. *The neck is, as a rule, bent backward* by the crushing of its posterior and more fragile part, or by its penetration into the trochanter posteriorly. In this latter way the trochanter may be split into two or many pieces. According to Stimson true impaction, or penetration with fixation, is the exception, but it is more common than in fractures through the neck. In this form *the cause* is usually a fall on the trochanter. The violence is greater than in the preceding form. This form includes most of those cases where fracture occurs before old age. According to Whitman, it is more common in childhood, and it is also found to be more common in early and middle adult life than was formerly supposed. *The axis of the neck and of the great trochanter* are not in the same plane, but meet in an angle, open posteriorly, at the anterior trochanteric line. In a fall on the trochanter this angle is exaggerated and the bone gives way

here at its weakest and most spongy portion. By this mechanism the fragments tend to be separated in front and driven together behind, causing penetration posteriorly, angular deformity of the neck, and outward rotation (eversion) of the thigh.

The *essential point in the functional prognosis,* and the reason for attempting to distinguish between these two forms, lies in the vitality and *power of repair of the upper fragment. This depends* not so much upon impaction or the situation of the fracture as upon the preservation of the blood supply, which runs toward the head in the thick cervical periosteum. These vessels are not much injured in fractures at the base of the neck, and in those through its narrow part we have seen that enough of the periosteum is usually untorn to preserve the vitality of the fragment. The number of specimens of undoubted bony union after fracture of the narrow part of the neck is sufficiently large not only to demonstrate its possibility, but to indicate that it is probably common enough, with proper treatment, to justify the attempt to obtain it whenever possible.

Symptoms and Signs.—The symptoms and signs of fracture of the neck of the femur, *upon which the diagnosis depends,* are (1) interference with function, (2) localized pain on movement, (3) position of the limb, (4) crepitus, in a few cases, (5) enlargement or widening of the great trochanter from comminution, especially in fractures at the base of the neck, and from infiltration of the overlying soft parts, (6) elevation of the trochanter and its approach to the median line, (7) swelling and diminished depressibility of the region below the outer half of Poupart's ligament. In addition to these the cause of the injury is important, especially if it be trifling and in an aged person. As to *the posture,* the injured limb is almost always everted, slightly flexed, abducted, and it may appear shortened. *The eversion* is largely the effect of gravity in connection with the diminished activity of the muscles; it also depends upon the angular displacement from crushing and penetration posteriorly, with or without impaction. In addition the upward displacement relaxes the internal rotator muscles more than the external, so that the former can act only at great disadvantage. It is well to bear in mind that eversion and loss of function may be due to a simple contusion. Exceptionally inversion is present instead. *Shortening is due* (1) to over-riding and (2) to alteration of the angle of the neck, from crushing or penetration inferiorly; it varies from 2 to 6 cm. ($\frac{3}{4}$ to $2\frac{1}{2}$ in.). It is usually greater in fractures at the base of the neck. In those through the narrow part of the neck it may be slight or even wanting at first, and increases gradually, or sometimes suddenly, after a few hours or days. A slight primary shortening and its subsequent gradual increase is thought by many to be pathognomonic of fractures through the neck. The shortening also causes a broadening and thickening of the upper part of the thigh. Allis has called attention to the relaxation of the fascia lata between the crest of the ilium and the great trochanter as a result of the elevation of the trochanter. Rotation of the trochanter upon a shorter radius than normal, in rotation of the thigh, is a theoretical rather than a practical sign.

An exact diagnosis in all cases between "intracapsular" and "extracapsular" fractures is both impossible and useless. Some cases of fracture at the base of the neck (extracapsular) can be positively recognized by the splitting, broadening, and sensitiveness to pressure of the trochanter and by the immediate and considerable shortening. Likewise, slight violence, advanced age, great disability, and slight shortening point to fracture through the narrow part of the neck.

Treatment.—In general the treatment should aim to secure union, by means of fixation and traction. The full restoration of form and function is not often to be expected. Fairly good function is not uncommonly present after such injuries, even without bony union. Bony union is almost always accompanied by some deformity, shortening, eversion, and adduction, owing to the angle in the neck which points upward and forward, due to the crushing and impaction below and behind. The adduction prevents the compensatory abduction which would overcome the shortening, hence the patient limps. This may be largely obviated by treating the fracture by traction in the abducted position. In those not too old or infirm a still better result may be obtained by the method advocated by Whitman of first reducing the shortening and the angular deformity of the neck by traction in inversion and extreme abduction and maintaining extension in this position by a plaster spica.

Excessive violence that may tear the untorn portion of the periosteum of the neck should be strictly avoided; but traction in abduction produces no cross-strain, but is in line with this periosteum and has little tendency to tear it, unless the traction is very excessive.

Separation of the epiphysis, whose conjugal cartilage adjoins the head, and is entirely intracapsular, has been demonstrated by specimens in a few cases, but it is even rarer than fracture of the neck at the corresponding age, *i. e.,* before nineteen, when bony union occurs (see p. 499).

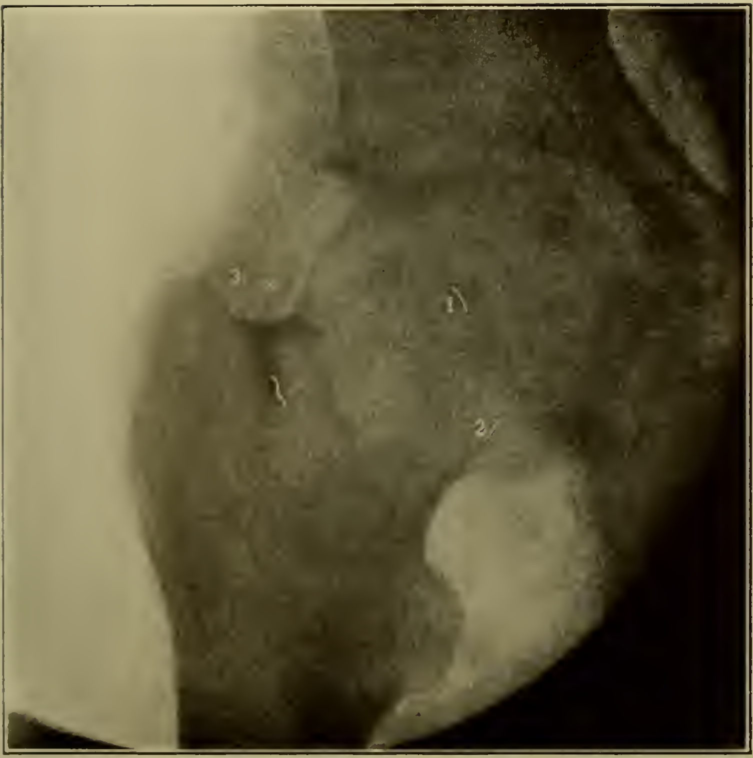
The **great trochanter** is formed as a *separate epiphysis,* which in a few cases has been observed to be separated from the shaft, sometimes as the result of osteomyelitis. Bony union occurs in the eighteenth year.

Coxa vara is an affection of adolescence, usually rachitic in origin. Under the weight of the body the neck yields, its angle with the shaft is reduced to 90 degrees or less, the limb is shortened, and the trochanter is elevated and made more prominent. Hence it may be mistaken for hip disease or congenital dislocation of the hip.

Excision of the head of the femur is sometimes called for in hip disease. The chief anatomical interest in the operation concerns the *method of reaching the deeply placed joint.* An **external incision** (Langenbeck's operation) has been much employed. With the thigh flexed at an angle of 45 degrees and rotated a little inward, an incision of 10 to 11 cm. (4 to $4\frac{1}{2}$ in.) is made in the long axis of the limb, so that one-third of the incision is over the great trochanter, a little behind its centre, the remaining two-thirds over the ilium, reaching up to the top of the great sciatic notch. In the position in which the limb is placed the incision would meet the posterior superior spine, if prolonged. The gluteal muscles are split in

PLATE XLIX

FIG. 171



Hip Joint. Anteroposterior strongly rotated outward. Male, aged twenty-four years.

1, border of acetabulum; 2, neck of femur; 3, apex of great trochanter.

line with their fibers, and the capsule is opened in the same line, and also transversely near the acetabulum. *By cutting the cotyloid ligament air is admitted* behind the head, thereby equalizing the atmospheric pressure on its two sides, so that it is readily separated from the acetabulum. This same procedure is carried out in exarticulation at the hip joint, but in the latter operation the ligamentum teres requires division, while in excisions it has usually disappeared as a result of the lesion for which the operation is required. Among the disadvantages of the external incision is the fact that many large and important muscles and many of the arteries that meet about the great trochanter are split or divided.

The method of anterior incision *of Hueter, Parker, or Barker* is an excellent one anatomically and practically. This is carried downward from 12 mm. ($\frac{1}{2}$ in.) below the anterior superior iliac spine; the tensor vaginæ femoris and the glutei muscles are retracted outward and the sartorius and rectus inward, exposing the capsule. No muscles and no vessels or nerves of any importance are divided.

Amputation or exarticulation of the thigh at the hip joint is performed by various methods. **The control of hemorrhage is the essential feature** of the operation and may be *accomplished* in *several ways:* (1) The femoral artery may be ligated before the flaps are cut, or while they are being formed, as in the "anterior-racket" incision. (2) The femoral may be compressed in the flap by the fingers of an assistant, just before the vessels are cut. The fingers are introduced behind the vessels, which are compressed between them and the thumb, which is on the surface. These methods do not control the bleeding from the branches of the internal iliac. Hence (3) pressure on the lower end of the aorta by Lister's tourniquet has been used and also (4) pressure on the common iliac against the pelvic brim by Davy's lever introduced into the rectum. Both 3 and 4 have been generally abandoned. (5) Pressure on the common iliac by the fingers of an assistant introduced through an intermuscular incision in the iliac region (McBurney) I have found very serviceable. (6) The elastic tourniquet around the upper end of the limb, with or without the use of long needles, or skewers, thrust through the upper end of the thigh, to prevent the rubber tubing or bandage from slipping down, is the *method most generally used.* In order to control the gluteal and sciatic vessels the tourniquet must be carried internal to the tuber ischii, so as to compress them as they emerge from the great sacrosciatic foramen. By passing over the groin it compresses the femoral vessels, and by being carried above the iliac crest it is prevented from slipping downward.

The *varieties of incision* are numerous. We may make an "external racket" or oval incision, with the summit 5 cm. (2 in.) above the trochanter; an "anterior-racket" incision, with the centre at the middle of Poupart's ligament; or a circular amputation of the thigh combined with an external vertical incision extending up 5 cm. (2 in.) above the trochanter, etc. The various incisions have their own advantages, and disadvantages. *The vessels divided* are the femoral, profunda, gluteal, sciatic, and branches of the external and internal circumflex, and the

long saphenous vein. Their position at the point of section varies with the form and length of the flaps. In those methods with long flaps the branches of the gluteal and sciatic arteries are small and unimportant. In the "anterior-racket" incision no tourniquet or compression is used, the vessels are tied as they are met with, as in removing a tumor, and very little blood need be lost. *The muscles* attached to the great trochanter and the upper end of the shaft are *divided* close to the bone; the other muscles, sartorius, rectus, adductors, gracilis and hamstring muscles, are divided at varying levels.

THE THIGH.

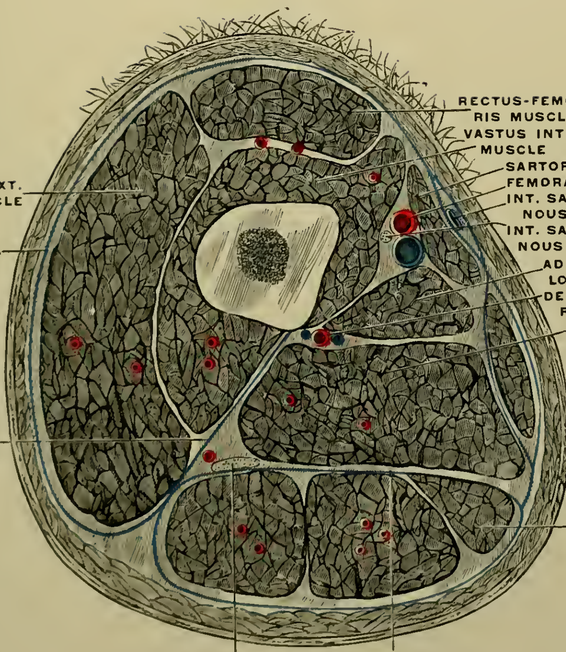
Limits.—Under this term is included the region lying below the regions last described, *i. e.*, below the level of the gluteal fold, and above the subcrural bursa at the knee, *i. e.*, a line 5 to 8 cm. (2 to $3\frac{1}{4}$ in.) above the patella. It is more or less conical in *shape*, and slightly curved with its convexity in front and externally. *On cross-section* it is round in the female, by reason of the subcutaneous fat, triangular in the male, with its base behind. The thigh is directed obliquely downward and inward, the inward obliquity being more marked in the female, on account of the wider separation of the acetabula, and also in those of short stature, on account of the shortness of the femora.

Surface Markings and Landmarks.—The *rectus muscle* forms a prominence in front, most noticeable when the muscle is in action, in flexion of the hip or extension of the knee. On either side of this prominence, and most conspicuous in the lower half of the thigh, is *a slight eminence* formed by the vasti muscles, the inner one being the more marked. Along the inner aspect of the thigh, from the apex of Scarpa's triangle downward, is *a groove* indicating the interval between the adductors and the quadriceps femoris. *In this groove lie* the femoral vessels and, more superficially, the sartorius muscle. The outer surface of the thigh is flattened or slightly depressed by the iliotibial band of the fascia lata. At the junction of the external and posterior aspects of the thigh the position of the external intermuscular septum, corresponding to the interval between the hamstring muscles and the vastus externus, is indicated by a slight depression, and is perceptible to palpation. The bone cannot be plainly palpated.

Topography.—The line of the femoral vessels (see p. 490) and of the sciatic nerve (see p. 487) have already been given. The *long saphenous vein* follows the course of the inner border of the sartorius muscle *in a line* from the saphenous opening (see p. 490) to the posterior border of the muscle at the level of the internal condyle. It is not infrequently double in the thigh. The *long saphenous nerve* follows the femoral artery, crossing to its inner side, in front of the artery, in Hunter's canal. Emerging through the anterior wall of this canal, it passes under cover of the sartorius in the lower fourth of the thigh, and lies to the inner side of the knee.

PLATE L

FIG. 172



Cross-section of the Middle of the Right Thigh. Upper segment of the section. (Tillaux.)

The Skin.—The skin of the thigh is coarse on the outer side, thin and fine internally, and is often used in *skin grafting*. Its *loose attachment* to the deep fascia *favors* the performance of *circular amputations*, as no dissection of a skin flap is required, merely the upward retraction by an assistant. Along the line of the external intermuscular septum it is a little more adherent, and may require freeing with the knife. *The laxity of the* **subcutaneous tissue**, which contains a very variable quantity of fat, allows the stripping up of large flaps of skin or the formation of extensive extravasations beneath it, in case of injury. *The long saphenous vein* is contained in this subcutaneous tissue.

The Fascia Lata.—The fascia lata resists and directs the extension of tumors, abscesses, and deep extravasations of blood, especially on the outer aspect of the thigh, where it is stronger. Through rents or cuts in the fascia lata the underlying muscle has occasionally bulged and been caught, forming a so-called *hernia of the muscle*. The quadriceps and adductor longus have been thus herniated. From the deep surface of the fascia two fibrous septa pass inward to the two lips of the linea aspera and divide the thigh into an anterior and a posterior compartment. This division has little surgical importance. The *internal intermuscular septum* separates the vastus internus from the adductors, and is very thin and unimportant. *The external* separates the vastus externus from the hamstring muscles. According to Tillaux, another septum, extending from the fascia lata, at the junction of its inner and posterior aspects, outward to the external intermuscular septum, separates the adductor from the hamstring group of muscles (Fig. 172).

The Femoral Artery.—The femoral artery may be ligated at any part of its course, which has already been given (see p. 490). The "**place of election**" is at the apex of Scarpa's triangle. It may also be ligated at the base of the triangle (common femoral) or in **Hunter's canal.** The latter *lies* at the lower end of the middle third of the thigh, beneath the sartorius muscle, which is retracted internally to reach it. It *measures* 5 to 6 cm. (2 to $2\frac{1}{2}$ in.) in length, and is *bounded* by the adductor longus behind, the vastus internus externally, and in front by a firm membranous layer of oblique tendinous fibers passing from the adductors longus and magnus downward and outward to the vastus internus. The *vein here lies* behind and somewhat external to the artery, quite closely connected with it, and an extra vena comes may lie in front of the artery and complicate its ligation. The *long saphenous nerve* lies in the canal, in front and slightly external to the sheath of the vessels. Within the canal it crosses in front of the vessels, which it accompanies to the opening in the adductor magnus, where it perforates the canal and passes beneath the sartorius. The vastus internus separates the artery from the femur, so that in *compression of the artery*, which must be made from within outward, there is no firm bed against which to compress it. In rare instances the femoral artery is replaced by two trunks. It is occasionally ligated for popliteal aneurysm or for wounds.

The Great Sciatic Nerve.—The great sciatic nerve usually *divides* into the internal and external popliteal nerves about the middle of the

thigh, and its internal popliteal branch continues the direction of the trunk; not infrequently it bifurcates higher up, even within the pelvis, and occasionally lower down. Below the lower border of the gluteus maximus it is quite superficial, and a little lower is crossed by the biceps. *At the middle of the thigh it lies* between the biceps behind and the adductor magnus in front, beneath or anterior to the thin fascial layer separating the hamstring and adductor muscles. Lower down it lies between the hamstring muscles which are internal and external to it. It is *surrounded by* a layer of loose connective tissue and fat, continued downward from the pelvis. This tissue affords a favorable pathway for the sinking of abscesses from the pelvis, even to the lower thigh or the popliteal space. The place of election for opening deep abscesses of the thigh or the removal of sequestra from the femur is the external surface, for here the bone is not very deep and there are no important vessels or nerves.

Fractures of the Femur.—The shaft of the femur may be fractured at any part, but *most commonly in the middle third,* which is affected by the leverage of both ends. The fracture is *usually oblique,* but may be transverse, especially in children and in direct fractures, which are most common in the lower half. Fractures in the upper half are almost always oblique. The obliquity usually corresponds to the normal curvature of the bone. Thus *it commonly runs* from behind forward and downward in the middle third, forward and outward in the upper third. *The displacement* is marked and is *the result of* the fracturing violence, the contraction of the thigh muscles, and the swelling beneath the firm fascia lata, by reason of which the thigh is necessarily *shortened* at the same time that it is broadened by the swelling. In addition there is *an angular displacement,* usually *directed* forward, or forward and outward, in the direction of the natural curve, and attributed to the contraction of the adductor muscles, which form the chord of the arc of the curve. The lower fragment may also be rotated out by gravity. In *fractures of the upper third* the usual forward and *outward displacement* of the lower end of the upper fragment is largely *due to muscular action.* (1) The adductors and hamstring muscles draw the lower fragment up and in, behind the upper fragment, and tilt the latter forward and outward, or according to the obliquity of the fracture. (2) The psoas and gluteal muscles also draw the upper fragment forward and outward. The sharp ends of an oblique fracture, especially the lower end of the upper fragment, may be driven into and caught in the surrounding muscles, which, being interposed between the fragments, prevent reduction of the deformity and lead to delayed union or non-union. *The artery or vein* are *rarely torn or compressed* by the fragments, an injury leading to gangrene. I have seen one such case in the lower third, where the danger of this complication is greatest. In *fractures in the lower third* the lower fragment may be tilted backward, probably by the action of the gastrocnemius. This tilting is the most difficult element of the deformity to reduce and keep reduced. It necessitates flexion at the hip and knee to relax the muscles concerned, and con-

tinued flexion of the knee to relax the gastrocnemius and prevent recurrence of the displacement.

Except in rare cases of transverse or incomplete fractures, *the limb is* always **shortened.** This shortening may vary from 0.5 to 10 or even 15 cm. ($\frac{1}{4}$ to 4 or even 6 in.), and is *due to* the over-riding and the angular displacement of the fragments. A principal *object of treatment* is the *overcoming of this shortening by continued extension.* Practically union never occurs without slight shortening, though the possibility of union without shortening may be admitted. The *average amount of shortening after union* is 18 mm. ($\frac{3}{4}$ in.), though 3.5 cm. ($1\frac{1}{2}$ in.) of shortening may occur without a limp in the gait, the shortening being compensated by the tilting of the pelvis. In this connection it may be noted that the *lower limbs are usually of unequal length,* the inequality averaging 6 mm. ($\frac{1}{4}$ in.), the left being the longer, as a rule (Wight). In only about 10 per cent. of cases are they of equal length, so that using one limb as a standard of length for the other is inaccurate, if the difference in length is trifling. In the *treatment of fractures of the upper third* the entire limb should be flexed and abducted to coincide with the forward and outward tilting of the upper fragment. In transverse fractures with over-riding this displacement must be corrected so that the ends may come in apposition. To allow this replacement anesthesia should be given to cause complete muscular relaxation, without which reduction can hardly be accomplished by traction.

In amputation at or below the middle of the thigh the *circular method* is easy and gives good results. The ease of retraction of the skin flap has been referred to, and the thigh is seldom so conical as to require the splitting of this flap. The *muscles retract unevenly,* those attached to the femur retracting but little, those not so attached, the free muscles (sartorius, rectus, gracilis, and hamstring muscles), retracting considerably. Hence the stump is retracted and the muscles are divided a second or even a third time.

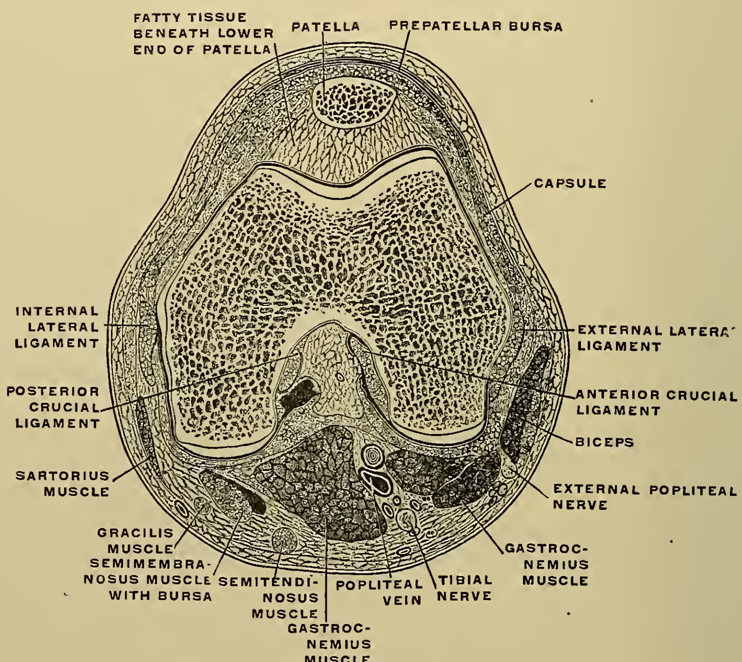
THE REGION OF THE KNEE.

Limits.—This includes the region between the level of the tubercle of the tibia and the level of the upper end of the subcrural bursa, 3 to 4 fingers' breadth or 5 to 8 cm. (2 to $3\frac{1}{4}$ in.) above the patella.

Landmarks and Surface Markings.—(1) **Anterolateral Region.**— **The patella** is plainly seen and felt in front, its inner border being somewhat the more prominent. In the extended position of the limb the patella can be moved to and fro, when the quadriceps is relaxed, but is drawn up and firmly fixed against the femur when the muscle is contracted. When the knee is flexed the patella occupies the hollow between the two bones, and is not so readily palpated. In this position we can feel, above the patella and through the quadriceps expansion, the *trochlear surface of the femur,* especially its prominent outer border. A line from the upper angle of this border to the adductor tubercle

marks the *level of the epiphyseal line. The adductor tubercle* is felt at the upper end of the internal condyle posteriorly. It is directly above the epiphyseal line and is the favorite situation for *exostoses* in adolescence. The *internal condyle* and its tuberosity are more prominent than the outer, but the *outer tuberosity of the tibia* is more prominent than the inner. The *tubercle of the tibia* is plainly felt at the upper end of the anterior tibial border, and at the lower end of the ligamentum patellæ. About on a level with the tubercle, *the head of the fibula* is felt on the postero-external aspect, 1 cm. (½ in.) below the joint line.

Fig. 173



Cross-section of the right knee joint, seen from above.

In the semiflexed position of the knee, when the quadriceps muscle is contracted, **the ligamentum patellæ** can be plainly felt, and often seen, as a ridge extending from the apex or lower end of the patella to the tubercle of the tibia. In this position there is a *slight groove* on either side of the tendon, but in the extended position, when the quadriceps is relaxed, the grooves are not marked. In stout subjects the grooves may be obliterated by fat, which in all cases is found most abundantly behind the upper half of the tendon, separating it from the synovial cavity. The ligamentum patellæ lies in the axis of the leg, and hence forms a slight obtuse angle with the direction of the quadriceps, which lies in the axis of the thigh. *On either side of the patella is a slight groove*, which is obliterated by effusion into the joint and may be filled with fat in the obese. In stout subjects the patella may appear to lie in the

bottom of a groove instead of on a ridge. *Above the patella is a depression* which is converted into a prominence in case of effusion into the joint. On both sides, but particularly on the inner side, **the interarticular line** between the tibia and femur can be felt as a slight depression in normal conditions. When the knee is extended this line is just above the level of the apex of the patella, which serves as a convenient landmark to it. It is here that one feels for a displaced semilunar cartilage. *The iliotibial band* of the fascia lata, descending between the patella and the back of the external condyle to the external tuberosity of the tibia, may be felt as a rounded band, most distinctly when the joint is forcibly extended. Its insertion is about midway between the apex of the patella and the head of the fibula.

Posterior or Popliteal Region.—In this region the landmarks are best felt when the knee is slightly flexed. In this position the concavity of the space appears, while in the extended position it is flat or bulging. **At the outer side,** behind the iliotibial band, the *tendon of the biceps* is felt descending to the head of the fibula. Directly in front of the tendon the upper part of the *external lateral ligament* is palpable in slight flexion, and close to the inner border of the tendon, posteriorly, the *external popliteal or peroneal nerve* is readily felt as a rounded cord. In its descent the nerve crosses the neck of the fibula, where it may be rolled under the finger, before it enters the peroneus longus. The *internal popliteal nerve* may be felt and, in thin subjects, even seen descending vertically in the middle of the space. **On the inner side** from without inward we can feel the long, slender, and more superficial tendon of the *semitendinosus,* more deeply and less distinctly the thicker and less prominent tendon of the *semimembranosus* and the *gracilis.* The last two appear as one tendon, but by a little manipulation we can insinuate the finger between them. The *popliteal lymph nodes* when normal cannot be felt. At the lower end of the space we can feel the converging fleshy heads of the *gastrocnemius.* In the flexed position a *crease in the skin* crosses this space some distance above the joint line. It disappears in extension.

Topography.—The popliteal artery, passing through the opening in the adductor magnus, enters the popliteal space beneath (anterior to) the semimembranosus, a little to the inner side of the middle line, and thence *runs in a line* to the interval between the two heads of the gastrocnemius at the centre of the lower end of the space. It descends at first obliquely outward, reaches the middle line opposite the joint, and thence runs vertically. It *bifurcates* on a level with the tubercle of the tibia. It lies against the back of the femur, the posterior ligament of the knee, and the popliteus muscle, and can be *compressed* against the femur in the upper part of the space, where also *its pulsations* can be felt. The **popliteal vein** lies behind or superficial to it, to its outer side above, but it crosses to its inner side below. The **internal popliteal nerve** descends in the middle line, continuing the course of the great sciatic, and is superficial to the vein, by which it is separated from the artery.

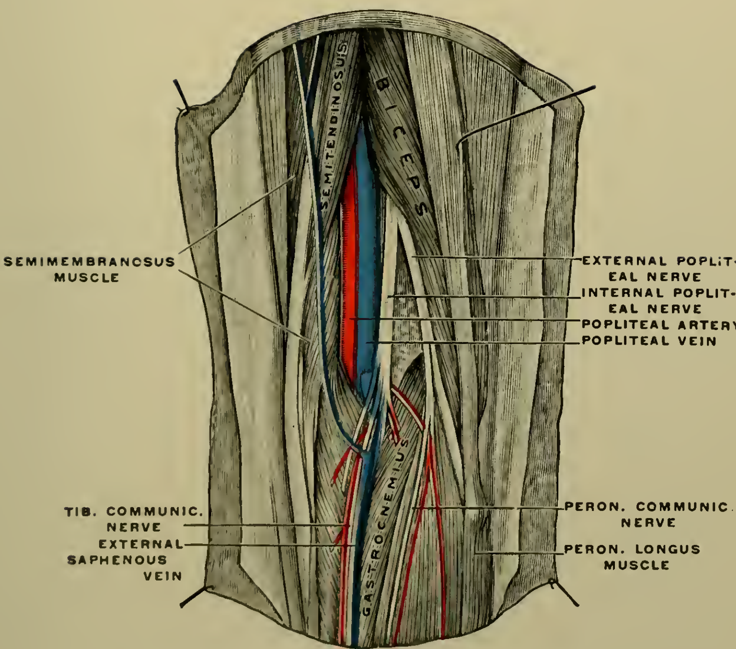
The superior *articular arteries* run transversely just above the condyles of the femur; the inferior articular arteries are just above the head of the fibula externally, and a little below the internal tuberosity of the tibia internally. The deep branch of the *anastomotica magna* descends in front of the adductor magnus to the internal condyle, the superficial branch runs with the internal saphenous nerve. The *short saphenous vein* perforates the deep fascia at the lower part of the popliteal space in the middle line. It is not visible, as a rule, unless varicose, and it has been suggested (Hérapat) that *varices* of this vein *may depend upon* a narrowness of the opening in the fascia. The *long saphenous vein* passes along the back of the internal condyle, above which it lies along the posterior border of the sartorius. It is joined by the *internal saphenous nerve* just below the joint line.

Soft Parts in Front of the Knee.—**The skin** is thick and very movable, thus protecting the joint from injuries or diminishing their gravity, and permitting incisions into the joint to be very indirect or valvular, which some advise in the removal of loose bodies in the joint. **The deep fascia**, continuous with the fascia lata, is *attached to* the two tuberosities and the tubercle of the tibia, and strengthens the joint on either side of the patella. This part of the joint is also strengthened by the *lateral expansions of the quadriceps tendon,* which are connected with the sides of the patella and the ligamentum patellæ anteriorly and reach as far as the lateral ligaments posteriorly. Hence they are called *lateral patellar ligaments.* In fractures of the patella, where there is any considerable separation of the fragments, there is always more or less of a tear in the lateral expansion on either side of the line of fracture.

There are **two bursæ** in this region that require mention: (1) **The prepatellar bursa** lies in front of the lower two-thirds of the patella and the upper end of the ligamentum patellæ. It does not reach the internal border, but often projects over the external border of the patella. Although it is often described as separating the patella from the skin, it lies, according to Tillaux, *beneath the deep fascia.* Others (Gruber, Joessel, etc.) describe bursæ in three situations, beneath (1) the skin, (2) the superficial fascia, and (3) the deep fascia, of which the last is the most constant. When more than one is enlarged, they are separated wholly or partly by septa which easily yield to inflammatory changes, so that in opening a purulent prepatellar bursitis a single cavity is often found. The bursa is *often enlarged* and not infrequently inflamed in those who kneel much, such as housemaids, etc., hence *prepatellar bursitis* is commonly known as "*housemaids' knee.*" Suppurative bursitis may lead to caries of the patella, from which the bursa is separated only by the periosteum. I have several times met with tuberculous inflammation of this bursa. (2) The *small bursa between the patellar ligament and the tubercle of the tibia* is separated from the synovial cavity by a pad of fat lying behind the upper end of the ligament. It does not communicate with the joint and is not often enlarged or inflamed. An indistinct feeling of fluctuation on either side of the upper end of the patellar ligament is often due to the loose fat beneath it and not to an

PLATE LI

FIG. 174



Popliteal Region of the Right Side. (Joessel.)

enlargement of this bursa. This fat often protrudes a little on either side of the ligament, and thus still further simulates an enlarged bursa.

Soft Parts at the Back of the Knee.—The soft parts at the back of the knee either bound or are contained in the popliteal space. **The skin** covering it is not so movable as in front, and the contraction of a cicatrix resulting from burns, ulcerations, or injury may result in a bent knee. In straightening a knee, long ankylosed in the flexed position, the skin at the back is liable to be torn. **The deep fascia**, continuous with the fascia lata above, has no bony attachments here. Its firmness limits the extension toward the surface of popliteal tumors or *abscesses*. Hence, being pent up in the popliteal space, they cause severe pain and tend to spread down into the leg or up into the thigh. From the latter region abscesses may extend to the popliteal space through the opening for the femoral vessels in the adductor magnus, or they may follow the great sciatic nerve from the thigh, the buttocks, or the pelvis.

The Muscles.—The muscles which *bound the space*, and give it a lozenge shape, are the biceps above and externally, the semitendinosus and semimembranosus above and internally, and the two heads of the gastrocnemius below and on either side. The upper muscles, known as *the hamstring muscles*, are the cause of flexion of the knee in knee-joint disease, from the irritation of articular filaments of the sciatic nerve, motor branches of which supply these muscles. Continued flexion in this disease leads to a *partial backward luxation of the tibia* and to the *contracture and shortening of these muscles*. According to Tillaux, the biceps and semitendinosus are frequently shortened in these conditions, the semimembranosus rarely so. The shortened tendons require tenotomy prior to straightening the knee. In *tenotomy of the biceps* the relation of the external popliteal nerve just internal to it is to be borne in mind. Contraction or contracture of the muscle renders the tendon more superficial and increases its distance from the nerve. To diminish the risk of cutting the nerve the tendon should be cut from within outward about 3 cm. ($1\frac{1}{4}$ in.) above the head of the fibula. The *hamstring tendons*, especially the biceps, may be *ruptured* by violence in the position of extreme flexion of the hip while the knee remains extended, a position in which they are greatly stretched.

The Popliteal Vessels.—The popliteal vessels lie deeply and are well protected, hence they are seldom wounded. The artery, however, is more often the seat of **aneurysm** than any other, with the exception of the thoracic aorta. Many factors have been adduced *to account for this disposition*. (1) It divides into two large vessels, which increases the blood pressure above the bifurcation. (2) It is supported by the lax tissue of the popliteal space and not by muscles. (3) Its course is curved, in the flexed position, like the thoracic aorta, so that the pressure is unequally distributed. (4) It is subjected to the strain of frequent and extensive movements. Thus forced flexion of the knee diminishes or arrests the flow of blood below and increases the pressure above the angle in the artery. When the artery is the seat of an aneurysm, the pressure exerted by forced flexion of the knee stops the circulation, and

popliteal aneurysms have been successfully treated in this way. Extreme extension of the knee may so stretch the artery, which is said to be unusually liable to atheromatous changes, that the inner and middle coats may become thinned or ruptured. The *relations of the artery* to the vein and the internal popliteal nerve explain the edema of the leg and the nerve symptoms due to the pressure of an aneurysm on these structures. The close relations of the artery to the posterior ligament, on which it lies, explains the occasional penetration of an aneurysm into the joint. In straightening the bent knee in cases of chronic knee-joint disease the artery may be ruptured. In this respect cuneiform resection of the knee is a safer operation than forcible straightening. The artery is more closely connected with the posterior ligament below than above the joint line, hence Tillaux recommends sawing the tibia from behind forward in resection of the knee to avoid accidental wound of the artery, but this is not necessary with ordinary care. A backward luxation of the tibia has occasionally been complicated by rupture of the artery. *Anomalies* of the artery are rare and consist mainly in a high division.

The **popliteal vein** is so *closely adherent to the artery* that some difficulty may be found in separating the two in ligature of the latter. In spite of its more superficial position than the artery, the vein is ruptured by violence even less often than the artery, and, according to Treves, never alone. This may be owing to the circumstance, noted by Tillaux, that it is so *thick* that it does not collapse on section, and thus resembles an artery so closely that it may readily be mistaken for it in operations on the cadaver.

The **lymph nodes** of the popliteal space consist of four or more small nodes, one just beneath the fascia and below the opening for the short saphenous vein, the others situated more deeply along the popliteal vessels. They are rarely swollen, and, when involved, form a median tumor unlike those derived from the bursæ.

Bursæ.—The bursæ at the back of the knee are situated *on either side*, two on the inner and four on the outer side. Many of these are not constant and are unimportant on account of the fact that they never communicate with the joint and are seldom enlarged.

(1) Between the internal condyle and the inner head of the gastrocnemius, and extending between the latter and the semimembranosus, is *the largest bursa* of this region and *the one most often inflamed.* It *communicates with the joint* in fully 50 per cent. of cases (Gruber), and more often in adults and in robust subjects. Its slit-like opening into the joint may become closed by the tightening of the posterior ligament in extension, which may explain its firm feeling in extension, in contrast with its more flabby feeling in flexion. In the latter position it may sometimes entirely disappear on pressure. It may become enlarged in effusions into the joint, or independently. (2) A small inconstant bursa, between the semimembranosus and the internal tuberosity of the tibia, may communicate with (1), but never directly with the joint. *On the outer side* there is (3) a bursa between the popliteus tendon and the external lateral ligament, without joint connection

except occasionally, and (4) one between the same tendon and the external tibial tuberosity. This bursa is strictly a *diverticulum from the joint* and, by occasionally *communicating with the upper tibiofibular joint* (in about 14 per cent. of cases, Gruber), connects the latter with the knee joint. (5) A bursa between the outer head of the gastrocnemius and the external condyle is neither constant nor connected with the joint. (6) One between the biceps and the external lateral ligament is more constant, but is also not connected with the joint. It is closely related to the peroneal nerve. Tumors due to a *bursitis* are situated *laterally and usually internally,* because (1) is most often enlarged, but median cysts may occur in the popliteal space, due to the hernial protrusion of the synovial membrane through small openings in the posterior ligament. Bursitis may cause stiffness of the joint and pain on extension. It may be distinguished from aneurysm by its lateral position, its lack of expansile pulsation, and the fact that compression of the femoral does not affect its size.

The Knee Joint.—The knee joint *owes its strength* to that of the ligaments, tendons, and fasciæ which join together and surround its component parts. By reason of its strength and the large extent of its opposing surfaces, traumatic **dislocation** is *uncommon* in spite of its exposure to injury, and only occurs from severe violence. The most common form is dislocation of the tibia forward by direct violence or by hyperextension; the next commonest is dislocation of the tibia backward. The *lesion is a grave one* because of the great violence required and the frequency of compounding and of injury of the popliteal vessels.

When the femur is held vertically the plane of the lower surfaces of the two condyles is not horizontal, as is that of the upper surfaces of the tibia, but the longer *inner condyle* projects *lower than the outer.* Hence to make the joint surfaces parallel the lower end of the *femur must be inclined inward,* the position it normally occupies in the body. It forms an angle with the tibia of about 172 degrees, opening outward. Another result of this inclination is to bring the knees together, although the hips are widely separated, and, as the tibia descends nearly vertically, the ankles are also in contact. In the normal erect position the line of gravity descends through the external condyle and tuberosity.

In the condition known as **knock-knee or genu valgum** the knee is unusually prominent internally. This condition is usually bilateral. It is *due to* a downward projection of the internal condyle, due to an inward bending of the lower end of the diaphysis of the femur, causing an obliquity of the epiphyseal line (Mikulicz). In most cases there is a similar, slighter, upward prominence of the internal tuberosity of the tibia. In addition, there is contraction of the biceps, the capsule, and the ligaments on the outer side and relaxation of the ligaments on the inner side. The usual cause is rickets, in which the distortion of the bones is commonly the primary factor, and the deformity occurs most often between the ages of two and four years. But it may occur in adolescents or from any injury or disease that weakens or relaxes the ligamentous structures on the inner aspect of the joint. In adolescents, etc., the

weakness of the supporting muscles causes the assumption of the "attitude of rest," with the feet separated and everted. This transfers the strain of standing from the muscles to the ligaments and causes a stretching and elongation of the internal lateral ligament. The normal pressure thus removed from the growing bones on the inner side by their slight separation there follows an overgrowth of the diaphyses, on this side, beyond the epiphyseal lines of both bones, especially of the femur. The increase of pressure on the outer side results in atrophy of the bones, contraction and shortening of the external lateral ligament, of the iliotibial band, and of the biceps tendon, which further increase the deformity. The prominence of the internal condyle is readily recognized when the knee is sharply flexed. It is a curious fact that *the deformity*, however great, *disappears* completely *when the knees are flexed.* This is because the deformity is due to the downward projection of the internal condyle, so that the axis of the hinge motion is not transverse but inclined outward and upward, bringing the feet away from one another when the knees are extended, but together when they are flexed. It may also be due to the outward rotation of the femur that accompanies the flexion.

Besides the characteristic deformity of knock-knee, the tibia is apt to be rotated outward, the femur inward, and flat-foot (talipes valgus) is likely to result. It may also be a cause of genu valgum. In walking the knees "interfere," and in extreme cases there is a swaying movement from side to side to allow the knees to pass one another. Knock-knee, when well established, is *treated by osteotomy of the femur* above the condyles, with or without the removal of a wedge of bone (cuneiform osteotomy), and then by straightening the limb. In Macewen's operation, the one usually practised, the femur is divided from the inner side, transversely to its long axis, in a line 12 mm. ($\frac{1}{2}$ in.) above the top of the external condyle. This is above the epiphyseal line, the synovial membrane, and the superior articular vessels; below and in front of the anastomotica magna.

Ligaments.—In the semiflexed position of the joint most of the ligaments are relaxed, a condition that favors the backward displacement of the tibia by the contracture of the hamstring muscles, in chronic knee-joint disease with flexion. Owing to the relaxation of the ligaments in this position rotary and slight lateral motion of the knee is allowed in semiflexion. Hence if we wish to *test the knee for abnormal lateral mobility*, such as is due to rupture of the lateral ligaments, etc., the test should be made *when the knee is extended.* All except the anterior ligaments are taut in extension, only the posterior crucial and the anterior ligaments are taut in extreme flexion. The powerful crucial ligaments are not relaxed in any position of the joint. The anterior crucial not only resists hyperextension and anterior displacement of the tibia, but also rotation of the leg inward. The posterior crucial ligament resists forced flexion and posterior displacement of the tibia. The lateral ligaments lie behind the centre of the joint, about the junction of its middle and posterior thirds, hence they are taut in extension, relaxed in flexion. In the latter position they resist outward rotation of the tibia.

PLATE LII

FIG. 175

Left Knee Joint. Knee slightly flexed. Internal condyle on the plate. Male, aged twenty-eight years.

1, external condyle; 2, internal condyle; 3, external tuberosity of tibia; 4, internal tuberosity of tibia

They are not very strong. If pus within the joint escapes into the popliteal space it usually does so through the thinnest part of the posterior ligament, the part below the oblique ligament of Winslow.

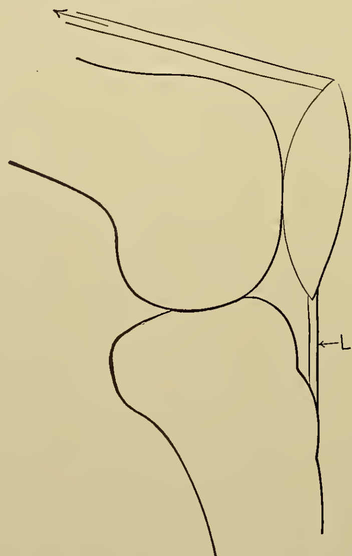
When one is in the act of falling backward, or in any direction with the knees bent, an instinctive effort is made to avoid the fall by violently contracting the quadriceps to straighten the knee. *By such a spasmodic contraction* of the quadriceps *one of four lesions may be caused:* (1) Fracture of the patella; (2) rupture of the ligamentum patellæ; (3) rupture of the quadriceps tendon; (4) dislocation of the patella.

Fracture of the Patella.—Fracture of the patella is the commonest of these. The fall of the patient is usually only indirectly the cause of the fracture, and it is often the result. In a fall on the bent knee, when the hip is also flexed, the tubercle of the tibia and not the patella comes in contact with the ground. In some cases, however, the patella is broken by direct violence, as by a blow or a fall directly on the bone. In over 80 per cent. of cases the fracture is *due to muscular action,* which is a more common cause of fracture in case of the patella than in any other bone. The *line of fracture* is quite uniformly *transverse* or slightly oblique when due to muscular action, and usually at or just below the centre of the bone. Fractures due to direct violence may be transverse, oblique, comminuted, or even longitudinal. Another important difference lies in the fact that *in direct fractures* there may be *little or no separation* of the fragments, *in indirect fractures* there is usually some and often *considerable separation.* This *separation depends upon* the amount of *effusion* into the joint, and of the transverse *laceration of the lateral patellar ligaments* and the capsule. The influence of the latter is seen in direct fractures, in which, though there may be considerable effusion, there is often little or no separation, for the lateral patellar ligaments are practically intact, unless vigorous or repeated action of the quadriceps extensor has followed the fracture. Again, in fractures due to muscular action the lateral patellar ligaments are more or less extensively torn, but the *separation* disappears or may be *easily overcome if the effusion is gotten rid of.* With the knee extended to relax the quadriceps tendon the pull of the latter is not an important factor in the separation until later on, after atrophy of the muscle occurs.

The rupture of the lateral patellar ligaments and the capsule on the sides, and the failure of bony union are explained by the *mechanism of fracture by muscular action* (Fig. 176). In the semiflexed position, in which the knee is usually placed when the violent contraction of the quadriceps occurs, only the middle of the back of the patella rests on the trochlear surface of the femur, the upper and lower ends of the bone being unsupported. Its vertical axis is in line with the taut ligamentum patellæ, while the line of action of the violently contracted quadriceps muscle (indicated by the upper arrow in Fig. 176) is nearly at right angles to this axis. The *patella* is thus *broken as one would break a stick over the knee.* It may also be fractured by direct traction. In either case the bone gives way first and, the force continuing, the fragments are separated and the tear extends a variable distance into the lateral patellar liga-

ments and the capsule on either side of the line of fracture. After the patella is fractured, and the fragments begin to separate, the *periosteum and tendinous fibers* in front of the patella do not tear at once, but *stretch* a certain distance. But if the fragments are pulled further apart, these fibrous structures *give way,* usually at a level different from that of the fracture (above or below) *and curl back* in front of one or both fractured surfaces. Atmospheric pressure acting on the gap between the fragments may help to force these fibrous fringes between the fragments. *This interposition of fibrous tissue* between the fragments *prevents the bony union* of these surfaces and often prevents crepitus when the surfaces are rubbed together. The interposition of blood clot and synovial

Fig. 176



Schematic outline of the knee joint to show the mechanism of fracture of the patella by muscular action. The upper arrow represents the line of action of the quadriceps muscle; *L*, the ligamentum patella.

fluid may contribute to prevent bony union. This is the reason why *treatment by open operation,* in this the commonest variety of fracture of the patella, is in such favor, as it alone assures bony union. In the open operation the fibrous tissue between the fragments must be trimmed away and the blood clot removed. The tear in the capsule and the lateral expansions should be carefully sutured and the fragments brought in apposition by absorbable periosteal sutures, with as little handling of the joint as possible. In direct fractures I have secured bony union without operation, and this result is by no means rare. A fracture of the lower and non-articular end of the patella without injury of the synovial membrane is an anatomical possibility, provided the amount of separation is slight (Morris). In such a case the fat behind the lower end

of the patella saves the synovial membrane from injury. The patella, which is a sesamoid bone developed in the quadriceps tendon, does not ossify until the end of the second year, and may be congenitally absent. Sesamoid bones are said to exhibit a tendency to repair by fibrous union, and this may have a bearing on the common occurrence of fibrous union after fracture of the patella. Nearly all the arteries around the joint furnish blood to it.

Rupture of the Ligamentum Patellæ.—Rupture of the ligamentum patellæ is rare. Exceptionally the tendon is torn from its insertion into the tubercle of the tibia, and rarely (ten recorded cases) the tubercle is avulsed with the tendon.

Rupture of the Quadriceps Tendon.—Rupture of the quadriceps tendon above the patella is more common, but rare in comparison with fractures of the patella. It *results from* a violent muscular contraction, sometimes from a slight one when the muscle is diseased. A well-marked *depression,* occupied by a blood clot, is palpable and often visible above the patella. It may be partial or complete. Complete rupture of the tendon or ligament is *treated by* aseptic *suture.* In these three forms of injury the ability to extend the knee is lost or impaired.

Dislocation of the Patella.—Dislocation of the patella is rare. The *commonest form* is the *outward dislocation,* which may be complete or, more often, incomplete. It may be *caused by* a blow on the prominent inner border or, more commonly, by a violent contraction of the quadriceps muscle. It *occurs most often* in the extended position of the limb, when the front of the capsule and the lateral ligaments of the patella are most lax, and the patella is more prominent and exposed to direct violence. The line of action of the quadriceps, in the axis of the femur, is not the same as the axis of the patellar ligament, in the axis of the tibia. *When,* therefore, *the quadriceps contracts, the patella,* which lies at the angle of meeting of these two axes, *is pulled outward,* as the muscle and ligament tend to form a straight line. In knock-knee, therefore, the tendency to outward dislocation is increased by the greater angle betweeen the muscle and the ligament. The *outward dislocation* of the patella *is resisted by* the prominent outer margin of the trochlear surface of the femur and by the capsule and the internal expansion of the quadriceps. The latter may remain intact in an incomplete dislocation, but must be ruptured to allow a complete outward dislocation. In the latter form *the patella is displaced* to the outer side of the external condyle, and usually *lies* with the inner border directed forward and the posterior surface inward. In the production of the dislocation the patella may be raised by the quadriceps so as to pass outward above the prominent outer margin of the trochlea. The next most common form is the so-called **edgewise or vertical dislocation** of the patella. In the commoner variety of this form the inner border rests in or near the bottom of the trochlear groove with the outer border projecting forward and the anterior surface looking inward. This position is maintained by the tension of its fibrous attachments and the untorn portion of the capsule and the pressure of the overlying fascia and skin, like "a stick on end under a tightly stretched

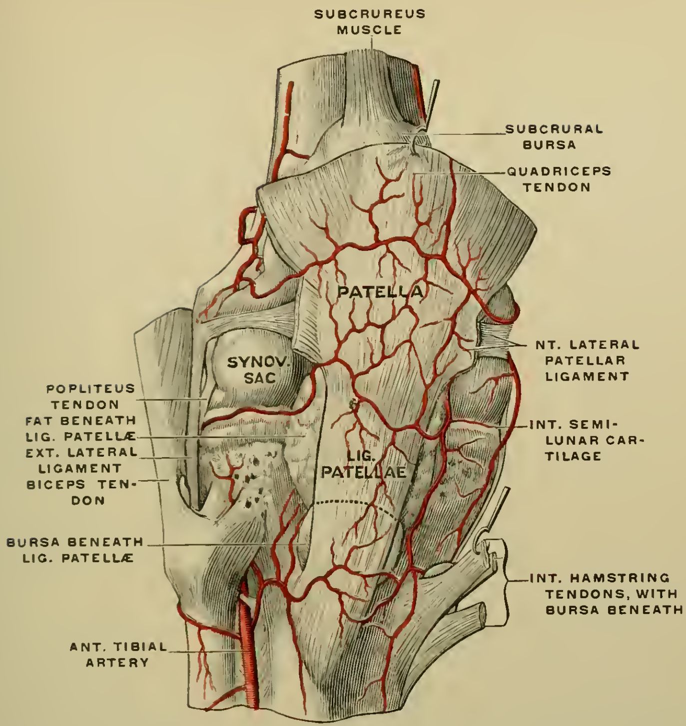
sheet" (Stimson). The reverse displacement is nearly as common. *Muscular action,* not always violent, seems to be the most *common cause* of this form also, but it may be due to a blow on the inner edge of the bone. *Inward dislocations* are rare.

The **semilunar cartilages** are attached by their peripheral surfaces to the capsule and lateral ligaments of the knee. In *effusions into the joint* one sees a groove in the bulging capsule on either side of the lower end of the patella, due to the lateral patellar ligaments and to this attachment of the semilunar cartilages, which incompletely divide the synovial cavity into an upper larger and a lower smaller portion. **Dislocation** of one or the other *of the semilunar cartilages* occurs, as a rule, from a twist of the leg in the semiflexed position of the joint. Flexion and extension of the knee occurs between the femur and these cartilages which move with the tibia, but in rotation one or the other disk is held firmly between the two bones, while the other is liable to be pressed or dragged so as to be nipped between them. Thus in rotation outward, performed chiefly by the biceps, the external meniscus is held closely between the outer condyle and the tibia, as these two are pressed together by the biceps. This increases the gap between the internal condyle and the tibia, into which the internal disk is liable to slip. Similarly in internal rotation the outer disk is the one liable to displacement. Hence the rule that *dislocation of the internal disk occurs from an outward twist of the knee, that of the external disk from an inward twist.* The internal disk is dislocated more than three times as often as the external, and the left knee is affected nearly three times as often as the right. This may be partly accounted for by the fact that outward rotation is more common than inward, and that the external cartilage is smaller, rounder, and more movable than the internal, and is attached partly to the posterior crucial ligament behind, and thereby to the femur, while the anterior crucial ligament is attached in front of and often to its anterior cornu, limiting its forward displacement. The popliteus, the chief internal rotator, grooves its outer surface, postero-externally, and may help to hold and steady it when it contracts in internal rotation. The *dislocated cartilage* is *torn* from its attachment to the tibia, usually at one end, and is displaced forward in most cases. At times it is pulled into the joint during flexion and rotation, where it becomes pinched and locked between the two bones, giving rise to a sudden pain and fixation of the knee in the flexed position, followed by a synovitis. On palpating the line of the joint we may *feel a gap,* when the disk is displaced into the joint, or a marked *ridge* when it is displaced laterally. The *displacement can usually be reduced* by extension followed by sudden flexion and rotation; but an operation is often required to effect a cure, by removing the loose portion or suturing it in position.

The Synovial Membrane.—The synovial membrane of the knee is the *most extensive* and complicated in the body. It extends as a *pouch between the quadriceps and the front of the femur* for about 2.5 cm. (1 in.) above the trochlear surface of the femur and the upper end of the patella. Above the pouch is **a bursa** (subcrural) between the quadriceps and the

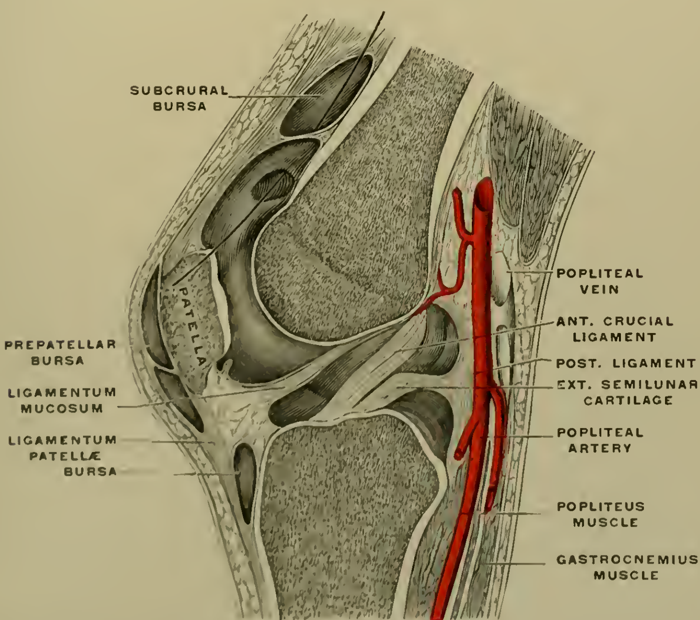
PLATE LIII

FIG. 177



Knee Joint from in Front, showing synovial sac, anterior ligaments, superficial anastomosis of articular arteries, etc. (Testut.)

FIG 178.



Lateral Half of Vertical Sagittal Section of Right Knee after Distention of the Synovial Sac. (Joessel.)

Probe passed through opening between pouch above patella and subcrural bursa.

front of the femur, over 2.5 cm. (1 in.) long vertically, which communicates with the pouch in 70 per cent. of cases in children and 80 per cent. in adults. The partition varies from a complete septum to a mere trace. In the extended position, therefore, we may find *a synovial cavity,* continuous with the joint, *over 5 cm.* (2 *in.*) *above the patella* or the trochlear surface of the femur, so that an anterior wound or incision at this level may practically open into the joint in a majority of cases. In extension the pouch is supported or pulled up by the subcrureus, while in flexion it is somewhat drawn down. *In case of effusion* into the joint *the pouch and bursa* appear as a *median prominence,* or, if separate and both are filled with effusion, as two prominences above the patella. In this condition of effusion into the joint *the patella is raised from the trochlear surface* of the femur, on account of its connection with the anterior part of the capsule, and is said to "*float.*" By sudden pressure on the patella the latter is made to strike the femur, producing a *click,* which is useful as a diagnostic sign of fluid in the joint. To produce this it is important to pull or press down the anterior thigh muscles so as to relax the tension of the quadriceps, which may be sufficient to hold the patella applied to the femur and prevent its floating.

The attachment of the posterior crucial ligament to the posterior ligament divides the synovial cavity, posteriorly, into an inner and an outer condylar recess. The upper third of the ligamentum patellæ is separated from the synovial membrane by a pad of fat, the lower two-thirds from the tibia by fat and a bursa. The synovial membrane is remarkable for the number of *fringes* from its inner surface, especially about the patella. Laceration, contusion, or pinching of these fringes, followed by their infiltration with blood, causes them to become enlarged and liable to be caught and pinched between the joint surfaces, causing pain and often synovitis. Their subsequent exfoliation may give origin to some of the "*loose bodies*" in the knee joint. Fibrinous or calcareous thickening in the synovial fringes, due to osteoarthritis, or embryonic remnants of cartilage in them, or the organization of an intra-articular clot or of fibrinous deposits in the joint may also produce similar "loose bodies."

Synovitis.—Synovitis from injury or exposure to cold is more frequent in the knee joint than elsewhere, owing to its superficial and exposed position and its exposure to wrenches and strains on account of the leverage of the long bones on either side of it. The floating of the patella and the bulging of the synovial sac above and at the sides of the patella have already been referred to (see above). At the sides of the patella the bulging usually shows some transverse constriction, owing to the resistance to the swelling of the firm lateral patellar ligaments. The swelling extends from 5 cm. (2 in.) above the patella nearly to the middle of the ligamentum patellæ. *In chronic inflammation* of the knee joint the latter almost always assumes **the flexed position**, which may be partly *explained as follows:* (1) The capacity of the joint is increased on moderate flexion, being greatest in flexion to 25 degrees and least in complete flexion. The knee, therefore, assumes the flexed position to

diminish the tension, which causes pain from pressure on the nerve endings. (2) Flexion relaxes most of the ligaments of the joint (p. 518), including the firmest and most resistant. (3) The irritation of the sensory nerves of the joint causes a reflex contraction of the muscles, supplied by the same nerves, which fix the joint and prevent motion, as that is painful. The flexor muscles are more numerous, more powerful, and more favorably placed for acting, and hence the joint is flexed. The flexed position, at first maintained by muscular action, is later on fixed by fibrous or bony ankylosis. If softening and lengthening of the ligaments occur from the joint disease, the pull of the flexor muscles may produce a posterior dislocation of the leg on the thigh.

To drain the knee joint, incisions may be made on both sides of the patella a little below its middle, but the only way to thoroughly expose and drain aseptic knee is to carry a free transverse incision into the joint below the patella, turn up the upper flap, and flex the opened knee. Owing to the size and complexity of the synovial membrane acute inflammation is apt to be serious, and subacute inflammation to become chronic.

Excision of the Knee.—Excision of the knee is sometimes required in chronic tuberculous disease (white swelling), or in case of a knee ankylosed from any cause in a strongly flexed position. Through an *incision* from the hind part of one condyle to that of the other, curving below the patella the joint is opened and the upper flap turned up. The internal saphenous vein and nerve need not be divided. When there is ankylosis with marked flexion we may remove a wedge-shaped segment of bone with the base anteriorly. In this way no undue traction is made on the popliteal vessels. *In sawing the femur* the section should be parallel with the normal joint surface, not at right angles with the shaft. If not properly sawed, knock-knee or bowlegs may result. Both bones are best sawed from before backward. With reasonable care there is no danger of wounding the popliteal vessels, although there is more danger while sawing the tibia than the femur (see p. 516). The operation should be done in such a way that *the limb* may be *absolutely straight.* In subjects who have not attained their growth *the greatest care* must be taken *to do no damage to the epiphyseal line,* for the greatest amount of growth in length occurs at this end of both bones. The level of the epiphyseal line of the femur has already been given (p. 512). The lower femoral epiphysis unites with the shaft about the twentieth year. The limits of *the upper tibial epiphysis* are indicated by a horizontal line just below the tuberosities, behind and laterally, so as to include the attachment of the semimembranosus and the facet for the fibula. In front it slants down on each side to meet just below the tubercle, which is included in the epiphysis. It unites with the shaft in the twenty-first or twenty-second year. **Arthrectomy** of the knee has replaced excision to a large extent, and is preferable in suitable cases.

Disarticulation.—Disarticulation at the knee may be done by (1) lateral flaps (Stephen Smith), (2) an elliptical incision, or (3) a long anterior flap. The best method is the first. In the method by a long

anterior flap there is danger of sloughing of the flap. All methods have the disadvantage of leaving a large surface of cartilage which has little or no reparative action. Hence I prefer Gritti's method, in which the lower surface of the condyles and the articular surface of the patella are sawed off and the sawed surfaces brought together. The patella, with the tough skin covering it, then forms the lower end of the stump.

Fractures of the Lower End of the Femur.—Besides the fractures of the shaft above the condyles (see pp. 510–11) we find: (1) intercondyloid fractures, (2) fractures of either condyle, and (3) separation of the epiphysis. In (1) *the line of fracture* between the condyles follows the intercondyloid notch in a sagittal plane and forms a T with the fracture separating both condyles from the shaft. (2) Fractures of either condyle are not common, and may be due to avulsion through the lateral ligaments, direct violence, or the pressure of the head of the tibia. The *fracture line* runs into the intercondyloid notch. (3) **Separation of the lower epiphysis** of the femur occurs *more often than that of any other* epiphysis. It is *commonly due* to great violence, acting especially in extending or abducting the knee. With singular frequency it has been due to the leg being caught between the spokes of a wheel. The separation here, as elsewhere, takes place between the cartilage and the shaft. The *periosteum is freely stripped up* from the shaft, but remains attached to the epiphysis. The epiphysis is commonly *displaced* forward and to one side, usually the inner. The injury is frequently compound, and the popliteal vessels have been torn or, more often, obstructed by pressure. Direct reposition has sometimes failed, owing to the presence of prominent lips on the epiphysis and to the tension or interposition of the periosteum. In such cases operative reposition, through an external incision, has given good results. Amputation has often been resorted to in the past, and several instances of arrest of growth of the femur have been reported.

Fracture of the Upper End of the Tibia.—This fracture is *not common*, less so than that of any other part of the bone. It may be *due to* severe direct or indirect violence, and *the line of fracture* may or may not involve the articular surface. Owing to the proximity of the knee joint, which is often involved directly or indirectly, an *effusion occurs* within the joint. *Separation of the upper epiphysis of the tibia* has been observed in a few cases. The upper end of the tibia and the lower end of the femur are *favorite situations for osteosarcoma.*

THE LEG.

As the limits of this region we may take the level of the tubercle of the tibia above and that of the base of the malleoli below.

Landmarks and Surface Markings.—The **anterior tibial border** or "shin" can be felt throughout its entire length. It is sharp and curved outward in the upper two-thirds; rounded, less prominent, and curved inward in its lower third, where it fades into the shaft and ends in-

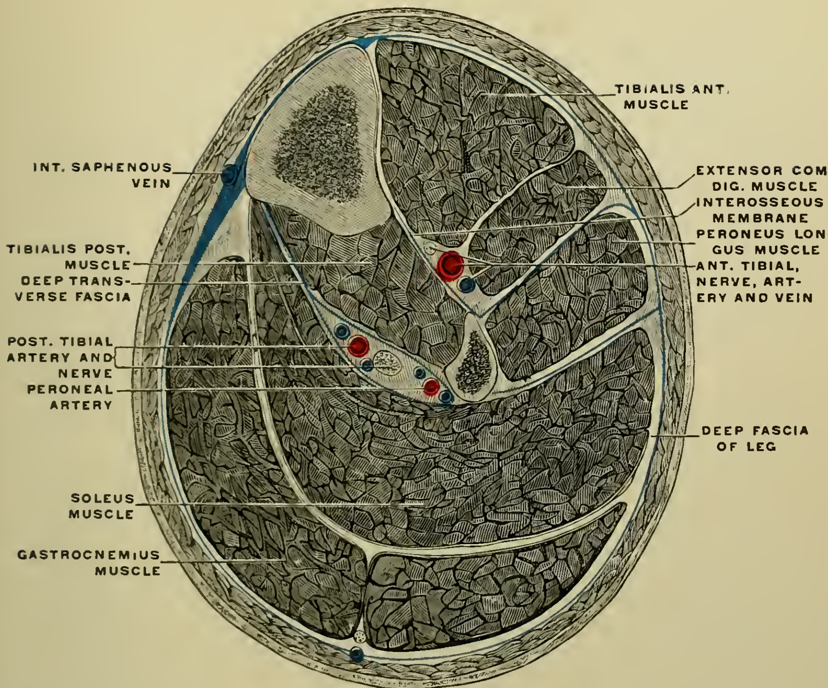
distinctly in front of the internal malleolus. The *inner border* can also be felt, from the tuberosity above to the malleolus below. The *internal surface,* between these two borders, is subcutaneous except above, where it is covered by the tendinous insertion of the sartorius covering those of the gracilis and semitendinosus. Although *the head of the fibula* is easily felt, *its shaft* is buried by the overlying muscles in its upper half. In its lower half it becomes palpable, especially in the lower 10 cm. (4 in.), where the malleolus and the triangular surface above it are subcutaneous. This subcutaneous area lies between the peroneus tertius and brevis. The fibula is well behind the tibia, so as to be posterior to the plane of the posterior border of the latter. *Anteriorly,* between the two bones, we can see the outline of the tibialis anticus internally, and external to it that of the narrower extensor communis digitorum can be made out when in action. The groove separating these muscles is quite distinct in muscular subjects, and forms the best guide to the anterior tibial artery. In the lower third of the leg the tendon of the extensor longus pollicis comes to the surface and can be felt between these two muscles. *Posteriorly* the prominence of the calf is mainly formed by the gastrocnemius, whose two heads are conspicuous when one stands on the toes. In this position it is seen that the inner head is larger and longer. In the same position *the Achilles tendon* stands out in prominent relief from about the middle of the leg to the heel. The soleus comes to view on either side of this tendon, but more especially externally, where it is less covered by the gastrocnemius.

Topography.—The **course of the anterior tibial artery** is indicated by *a line* from a point midway between the head of the fibula and the prominence of the outer tuberosity of the tibia to the middle of the front of the ankle joint, or of the space between the malleoli. The **posterior tibial artery** *runs* from the bifurcation of the popliteal, at the centre of the lower end of the popliteal space, opposite the lower end of the tubercle of the tibia and about 5 cm. (2 in.) below the joint, to the mid-point of a line from the tip of the internal malleolus to the lower and inner corner of the prominence of the heel. At this point *the artery bifurcates* into the two plantar arteries. About 2.5 cm. (1 in.), sometimes less (15 mm.), below its upper end the posterior tibial gives off **the peroneal artery,** which *runs* along the inner border of the fibula to about 2.5 cm. (1 in.) above the ankle joint, where it gives off the anterior peroneal.

The **internal saphenous vein,** arising from the venous arch on the dorsum of the foot, *runs* in front of the internal malleolus and thence just behind the internal border of the tibia to the level of the knee, where it lies just behind the internal condyle. The **short saphenous vein** passes behind the external malleolus and thence up the back of the leg to the lower part of the ham, where it perforates the deep fascia. Both the internal and external saphenous veins, but more especially the former, are visible beneath the skin unless the subcutaneous fat is very abundant. Both of the saphenous veins and of the tibial arteries are accompanied by nerves of the same name.

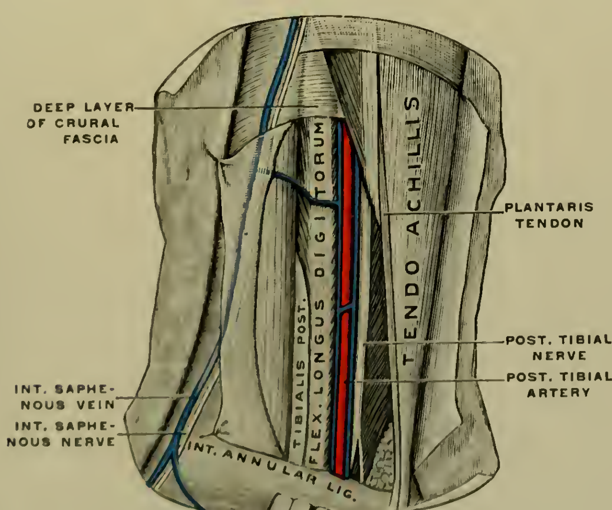
PLATE LIV

FIG. 179



Cross-section of the Lower End of the Upper Third of the Right Leg. Lower segment of the section. (Tillaux.)

FIG. 180



Internal Aspect of the Lower Half of Right Leg. Superficial dissection. (Joessel.)

The skin of the leg, especially anteriorly, is *more adherent* to the deep fascia than that of the thigh. Thus in circular amputations it is necessary to dissect up the skin flap and not merely to retract it. Owing to the conical shape of the leg, it may be difficult or impossible to dissect back this skin flap without splitting it on one side in the form of a cuff. The subcutaneous tissue of the leg, especially in front, contains comparatively little fat, so that the skin over the inner surface of the tibia lies *nearly directly on the bone.* The skin is here exposed to blows and kicks, which produce a degree of pain, bruising, cutting, ulceration, or even periostitis, far in excess of what a similar violence would produce elsewhere. *Ulcers and eczema,* as the result of varicose veins, are common in front of the leg, and run a very chronic course. Ulcers over the bone may expose the latter, lead to disease of its surface, and result in scars that are adherent to the bone.

In the subcutaneous tissue lie the superficial veins, nerves, and lymphatics. The *long saphenous vein* is not infrequently double in the leg, as it is in the thigh, the second trunk lying behind the regular course of the first trunk (see p. 526), that is, farther behind the internal border of the tibia. Most of the *superficial lymph vessels* accompany the long saphenous vein, and the majority of them are in front of it, while the *long saphenous nerve* usually lies behind and deeper than the vein. A few superficial lymph vessels accompany the short or external saphenous vein to the small popliteal nodes. The latter lymph vessels and the *short saphenous vein and nerve* are covered by a duplication of the deep fascia so that they are not strictly in the subcutaneous tissue. The *musculocutaneous nerve* perforates the deep fascia near the septum between the peroneal and extensor muscles at the upper end of the lower third of the leg. Thence it runs downward and inward in the subcutaneous tissue, so superficially that it is easily palpable, or even visible in thin subjects.

The Deep Fascia (Fig. 180).—The deep fascia closely invests the leg and in its upper third is adherent to the anterior but not to the posterior muscles. Although it is attached to the anterior and internal borders of the tibia, it is not wanting over its internal surface, as stated by Tillaux, but continues over this surface more or less adherent to its periosteum. It is *attached to* the head and the malleolus of both tibia and fibula, where it blends with the periosteum, and it is *continuous with* the fascia lata above and the annular ligaments and the fascia of the foot below. *Two septa* passing inward from the deep surface of this fascia, to be attached one to the anterior and one to the external border of the fibula, *enclose a compartment which lodges the peroneal muscles* and separates an anterior from a posterior compartment externally. These two main compartments are further separated by the bones and the interosseous ligament. The *posterior compartment is subdivided* into a superficial and a deep portion of a fibrous septum, the *deep transverse fascia,* which stretches across from the internal border of the tibia to the postero-internal border of the fibula, separating the soleus behind from the tibialis posticus in front. Below it separates the tendo Achillis from the deeper

structures. There is an *aponeurotic expansion in* the substance of *the soleus,* also connected with the internal border of the tibia, which may be mistaken for the deep transverse fascia in cutting through the soleus to expose the posterior tibial artery.

The Muscles.—The muscles lodged in the anterior compartment are so compressed within their firm osseo-aponeurotic walls that they form a protrusion or hernia when the fascia is torn or cut. *The plantaris tendon* has not infrequently been *ruptured,* producing a sudden sharp pain in the calf. The **tendo Achillis,** less often some fibers of the gastrocnemius, may be *ruptured* during violent exertion, especially at the narrowest and weakest point of the tendon about 3.5 cm. ($1\frac{1}{2}$ in.) above its insertion, or opposite the internal malleolus. But more often it requires **tenotomy** on account of its contracture. This is *best done* opposite its narrowest point by introducing the tenotome in front of the tendon at its inner margin, to avoid the posterior tibial vessels, and then cutting toward the surface. The *posterior tibial vessels,* however, lie beneath the deep transverse fascia and so far forward that they are in no danger of injury with ordinary care. The *short saphenous vein* is nearer, usually in front of the outer margin of the tendon, and may possibly be wounded. Its accompanying nerve is usually in front of the vein at this point. On section the tendon retracts within its sheath.

The Vessels.—The *anterior tibial and the peroneal arteries,* from their close relations with the tibia and fibula respectively, are liable to be *injured in fracture* of these bones. I have seen gangrene of the foot follow the rupture of the **anterior tibial artery** in a bad fracture of the tibia. The anterior tibial artery lies on the interosseous membrane in the upper two-thirds and in front of the tibia in the lower third. It lies *in the first intermuscular interval* on the outer side of the tibia, but the whitish line, which is said to indicate this interval on the surface of the deep fascia, is always indistinct and usually absent. The interval can be felt better than seen, and lies about 2.5 to 3 cm. (1 to $1\frac{1}{4}$ in.) from the crest of the tibia and a finger's breadth internal to the septum between the peroneus longus and the extensor communis muscles. The **posterior tibial artery** in the upper two-thirds of the leg is covered by the inner head of the gastrocnemius and the soleus, the former of which must be retracted outward, the latter divided to reach the artery. *The longitudinal incision* is carried 18 mm. ($\frac{3}{4}$ in.) behind the inner border of the tibia, where the long saphenous vein is to be avoided. *The artery is covered* by the deep transverse fascia in all parts of the leg, so that this, as well as the deep fascia, must be divided to expose it (Fig. 180). *In the lower third* of the leg *it becomes more superficial,* being covered only by the skin and deep fasciæ (two layers), and in thin persons it can be felt pulsating in the hollow on the inner side of the tendo Achillis. It is not often involved in fractures of the tibia, as it is separated from it, except at its lower end, by the tibialis posticus muscle. **The peroneal artery** in the greater part of its course is covered by the flexor longus hallucis, which must be divided or retracted in order to reach it. This artery also is beneath (anterior to) the deep transverse fascia. The

peroneal artery, by anastomotic branches at the lower end of the leg, takes the place of the posterior and anterior tibial arteries when the latter are rudimentary or wanting. The *bifurcation* of the popliteal, or sometimes that of the short tibioperoneal trunk, is *where emboli are apt to lodge. If gangrene results,* as not infrequently happens, the embolus is probably at the bifurcation of the popliteal, for in this case all three trunks are blocked. According to Joessel, not only the two regular venæ comites, but other veins, anastomosing across the artery, accompany the posterior tibial and increase the difficulty of its ligation.

Varicose Veins.—Verneuil thinks that the deep veins of the leg are more often varicose than those of the surface, and that this condition is indicated by aching of the legs and swelling of the feet in those who stand a great deal. *Varicose veins* are *more common in the leg* than elsewhere, with the possible exception of the spermatic and hemorrhoidal veins. This fact may be partly *accounted for by* (1) the length of the veins of the lower extremity, (2) the action of gravity in resisting their upward flow and in affecting the weight of the blood column which the valves have to support, (3) the liability to compression from the use of garters or from abdominal or pelvic growths or the pregnant uterus pressing on the external iliac trunk, which these veins ultimately enter. These causes act by increasing the pressure within the veins. Additional predisposing causes are (4) the loose support of the superficial veins and the lack of the assistance of muscular contraction, for the *saphenous veins* are thin-walled and lie outside of the firm deep fascia; (5) the increased resistance to the venous circulation where the superficial join the deep veins, and where varicosities often begin; (6) congenital defects in the valves. Varicose veins are *enlarged not only in diameter but in length,* hence their tortuous course. *The contour* is irregular and nodular, and the nodules, or enlargements of the vein, are found especially just above the valves and at points where the vein is joined by deep veins. At the latter points pressure is exerted from three directions: (1) the weight of the blood column above, (2) the blood current and the resistance of the valve next below, and (3) the inflow from the side, the force of which is increased by muscular contraction. I have seen men who could produce varicose veins at will by an upward movement of the deep fascia, which cut off, as it were, the saphenous veins where they penetrate it.

The Bones of the Leg.—The tibia bears the entire superincumbent weight. The fibula, besides affording attachment to muscles, plays an important part in the ankle joint and serves as a brace for the tibia, which increases its resistance to lateral strains. The smallest and *weakest part of the tibia* is at the junction of the middle and lower thirds, where, for its area, it bears a greater weight than any other bone (Humphry). The meeting here of the two columns, an upper and a lower, into which the cancellous tissue is divided (Fayel and Duret), and of the triangular upper two-thirds and the circular lower third, are thought to add to the weakness of the tibia at this point. Accordingly this is where most indirect fractures occur.

Direct fractures of the shaft of the tibia may occur *at any point,* and are often more or less *transverse,* so that there is little if any displacement. *If the fibula is broken* at the same time, as it is likely to be, the fractures of the two bones are about *on the same level.* The long, slender fibula, placed as it is on the more exposed aspect of the leg, would apparently be more often broken from direct violence but for its covering of muscles. When one bone alone is broken, the other acts as a splint and limits its displacement.

Indirect fractures are due especially (1) to a bending or flexion, or (2) to violence combined with torsion of the limb. In (1) the fracture may be *at any point* and is more or less *transverse* and dentated, hence there is little but angular deformity. In (2) the fracture is mostly in the *upper end of the lower third* (the weakest part) and is oblique, *the line of fracture* usually running downward, inward, and forward. *The fibula,* which is almost always broken in indirect fractures, breaks, as a rule, *at a higher level.* The sharp, lower end of the upper fragment of the tibia is liable to puncture the skin and compound the fracture from within. In one variety of this form of fracture, first described by Gosselin, the sharp ends of both fragments end in a triangular point, and from the bottom of the depression in the lower fragment antero-internally, corresponding to the point of the upper fragment, a fissure runs spirally downward and often enters the ankle joint.

Owing to the subcutaneous position of the tibia, its fractures are *frequently compounded,* from within in indirect fractures, from without or within in direct fractures. On the subcutaneous inner surface and anterior border we can detect even very slight displacements as well as other pathological conditions. In oblique fractures the *lower fragment is often drawn upward* and outward, behind the upper fragment, by the calf muscles and rotated outward by the weight of the foot, which has lost its continuity with the upper leg.

The tibia, more than any other bone, becomes bent in children with rickets. The bowing in "**bowlegs**" is *usually outward,* at times forward or outward and forward, giving a kind of spiral twist. It is *caused by* a tonic contraction of the muscles, and is increased by the weight of the child in walking. It is generally *most prominent at* the weakest part of the bone, the junction of the lower and middle thirds. *Genu varum,* in which the femur is abducted and rotated out and the tibia rotated in, causing a separation of the knees, is usually associated with some degree of bowlegs and the latter with some genu varum, so that the terms are often used synonymously.

Infectious bone disease, septic or tuberculous, is most common near the two epiphyses and at the weak point in the bone, which are particularly subject to strains, traumatisms, etc. If neglected they may invade the neighboring joint. The inner surface and anterior border are favorite situations for syphilitic nodes and periostitis, giving these parts a rough, irregular feeling.

In amputation of the leg *in the upper third the "place of election"* is a hand's breadth below the knee joint. This point was chosen as

giving a convenient length of leg stump for wearing a peg leg; for the knee is then bent and the weight is borne on the tubercle of the tibia. This line of amputation is at or just above the large nutrient artery of the tibia, which therefore does not cause trouble, as it may below. *At this level three arterial trunks* are met with, for the tibioperoneal trunk bifurcates 7.5 cm. (3 in.), or slightly less, below the knee joint. Throughout the leg *the two posterior arteries* are beneath the deep transverse fascia, or in a duplication of it, the peroneal behind the fibula, the posterior tibial behind the tibia and separated from it by the tibialis posticus and the flexor longus digitorum. The *anterior tibial* is to be sought in front of the interosseous membrane in the upper two-thirds and in front of the tibia below this. *In the upper third* of the leg *amputation by long external flap* is the best method, provided care is used to preserve the anterior tibial artery to the end of the flap, and not to bare the bone so high as to run the risk of injuring this artery where it comes forward above the interosseous membrane. *Circular amputation* is also suitable in the upper half, but less so below, on account of the conical shape and, in the lower third, the lack of a muscular covering. *In the middle third* amputation by a *long posterior flap*, including the superficial layer of muscles (Lee) or both superficial and deep muscles (Hey), is a favorite method. Owing to the danger of injury to the overlying skin from the pressure of the sharp angle of the shin, this angle should always be bevelled off after sawing the tibia.

THE ANKLE.

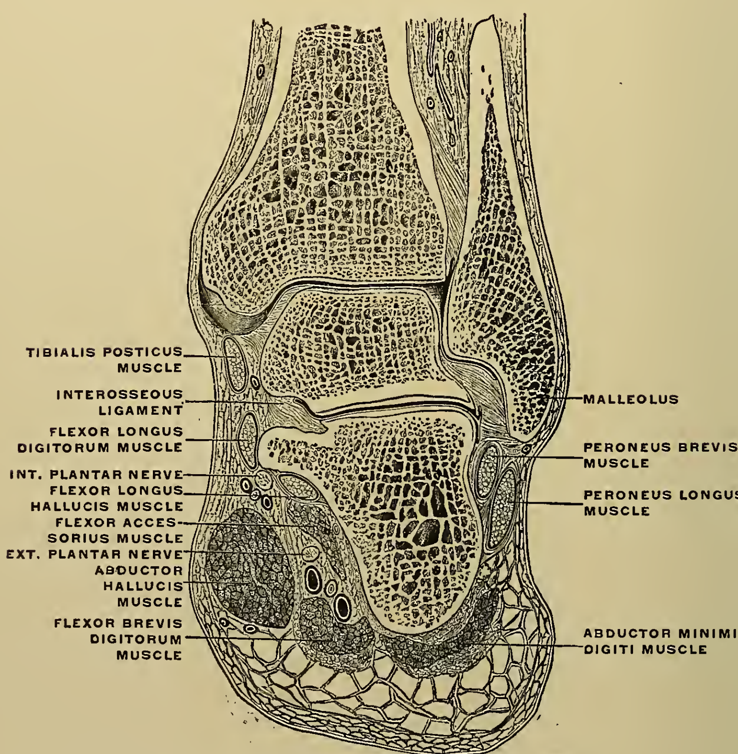
The **limits** of this region are artificial, and may be placed two fingers' breadth above and below the malleoli.

Landmarks and Surface Markings.—The **two malleoli** are prominent and very distinctly outlined. *The external* lies opposite the centre of the joint, descends lower by 12 mm. ($\frac{1}{2}$ in.), is slightly less prominent, and is 12 mm. ($\frac{1}{2}$ in.) behind the *inner malleolus*, anteriorly. But as the latter is broader anteroposteriorly, the posterior borders of the two are on the same level. The tip of the external malleolus lies opposite the posterior calcaneoscaphoid joint. According to Holden, the inner edge of the patella, the internal malleolus, and the inner side of the great toe should be in the same vertical plane, a fact to be noticed in setting fractures. *In front* of the ankle *the extensor tendons* form a prominence, which is very marked when they are in action in flexion of the ankle. From within outward we can distinguish the tendons of the tibialis anticus (the most superficial), the extensor longus hallucis, and the extensor longus digitorum, with the peroneus tertius. On either side of the prominence due to the tendons and in front of each malleolus is a *slight depression.* Opposite the joint line this depression corresponds to the thin anterior part of the capsule, and hence it is *replaced by a bulging in sprains, effusions* into the joint, tuberculous disease of the latter, etc. The *tendo Achillis* forms a marked prominence behind. *On either*

side of it, between it and the malleolus, is *a marked furrow. Along the inner furrow,* behind the inner margin of the tibia and the back of the malleolus, the tendon of the tibialis posticus can be felt, and behind and external to it that of the flexor longus digitorum. *Behind the external malleolus* the long and short peroneal tendons are palpable, the tendon of the peroneus brevis being nearer to the bone.

Topography.—The *line of the ankle joint* is 12 mm. ($\frac{1}{2}$ in.) above the tip of the internal malleolus. Opposite the bend of the ankle the anterior tibial artery becomes the **dorsalis pedis**, and, with the anterior

Fig. 181

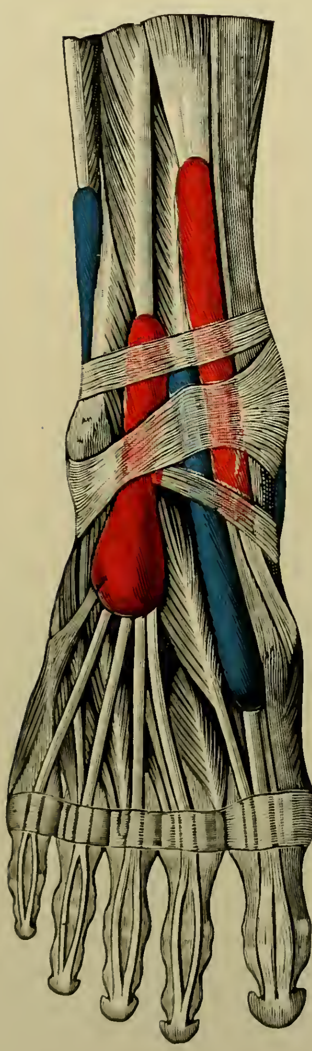


Frontal section of the right ankle, seen from behind.

tibial nerve, *lies* between the tendons of the extensors longus hallucis and longus digitorum, where its pulsation can be felt. *The line of the artery* is from the middle of the ankle to the proximal end of the interval between the first and second metatarsal bones. In some cases it describes a curve, concave internally. The *posterior tibial artery and nerve* lie behind the internal malleolus, external and a little posterior to the tendon of the flexor longus digitorum. The tendon of the flexor longus pollicis lies still more externally, at the back of the lower end of the tibia, midway between the two malleoli. The posterior tibial artery

PLATE LV

FIG. 182



The Anterior Annular Ligament of the Ankle and the Synovial Membranes of the Tendons Beneath it Artificially Distended. (Gerrish, after Testut.)

bifurcates into the two plantar arteries opposite the mid-point of a line between the tip of the internal malleolus and the lower and inner corner of the prominence of the heel. The *long saphenous vein ascends* in front of the internal malleolus, the *short saphenous* behind the external malleolus.

The Skin.—The skin covering the ankle is thin and loosely attached, and rests almost directly upon the bones, with the interposition of but very little subcutaneous fat. Hence it is readily contused or excoriated, as, for instance, by ill-fitting splints; and superficial gangrene may result from slight pressure, especially where the circulation is impaired by arteriosclerosis. Thus I have seen gangrene of the skin over the malleolus result from pressure against the mattress in sleeping, in the case of an old gentleman who had previously lost a toe from senile gangrene. **The subcutaneous connective tissue** is abundant only in front, where it readily allows considerable swelling or edema, and around the tendo Achillis, and only here is there any considerable amount of fat. The deep transverse fascia of the leg is continued down behind the tendons and vessels at the back of the internal malleolus. This fascia and a considerable amount of loose connective tissue and fat separate these structures from the tendo Achillis, so that in the tenotomy of the latter there is little or no danger of wounding the posterior tibial vessels.

The Deep Fascia.—The deep fascia, continuous with that of the leg above and the foot below, is *re-inforced* in front and laterally so as *to form firm bands,* known as **annular ligaments,** which bind down and keep in place the tendons in these situations. There are **two anterior annular ligaments,** of which *the upper* passes transversely between the anterior borders of the tibia and fibula and keeps in place the anterior tendons in the slender lower third of the leg. *The lower band* begins on the outer side of the calcaneum and splits into two layers, which pass one behind and one in front of the tendons of the peroneus tertius and extensor longus digitorum and then unite at the inner border of the latter. It again divides into two branches, of which the upper goes to the front of the internal malleolus, the lower to the scaphoid and the plantar fascia. This ligament *binds down* the tendons at the bend of the ankle and prevents them from projecting forward when in action. **The lateral annular ligaments** connect the back of the malleoli with the calcaneum on the corresponding side and prevent the dislocation forward of the tendons behind these two malleoli. As the result of violence these *lateral bands may be ruptured,* allowing one or more *tendons* to be *dislocated forward* onto the front of the corresponding malleolus. This has happened to the tibialis posticus and peroneus longus, and the latter is more often displaced than any tendon in the body, owing to the shallowness of the groove, the weakness of the external lateral ligament, the length of the slender tendon, and the sudden change in its direction below the malleolus. From the deep surface of the internal annular ligament processes pass forward to bony ridges at the back of the malleolus and the lower end of the tibia, thus forming *sepa-*

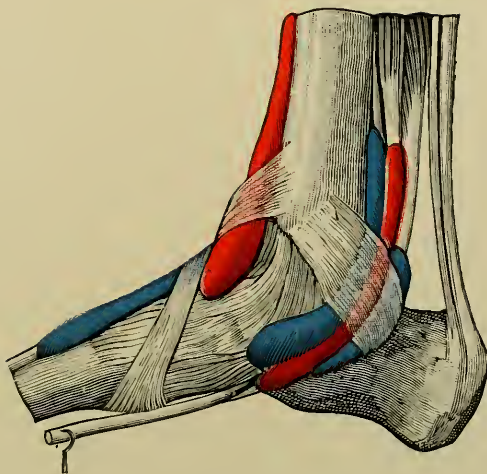
rate compartments for each of the three tendons here. Thus it happens that the tibialis posticus tendon may be displaced without the other two, which are farther from the inner surface of the malleolus.

In passing beneath the two lateral and the lower anterior annular ligament *the tendons are provided with* separate **synovial sheaths,** except that there is a common sheath for the two peroneal tendons and for those of the extensor longus digitorum and the peroneus tertius. *The synovial sheath* of the tibialis anticus extends from 5 to 6 cm. (2 to $2\frac{1}{2}$ in.) above the ankle joint nearly to the first metatarsal bone; that of the peroneal tendons from 3 to 4 cm. ($1\frac{1}{5}$ to $1\frac{3}{5}$ in.) above the joint to the calcaneo-cuboid joint; that of the extensor longus digitorum and peroneus tertius from 2 cm. ($\frac{3}{4}$ in.) above to 4 to 5 cm. ($1\frac{3}{5}$ to 2 in.) below the joint; that of the extensor longus hallucis from 1 cm. ($\frac{1}{2}$ in.) above the joint nearly to the metatarsus; that of the tibialis posticus from 5 cm. (2 in.) above the inner malleolus to the scaphoid, and that of the flexor longus digitorum from 3 cm. ($1\frac{1}{5}$ in.) above the malleolus to the sole of the foot, where it is crossed by the flexor longus hallucis and communicates with its sheath. *These synovial sheaths may become inflamed* and filled with fluid, and, as at the wrist, this inflammation is apt to be tuberculous, with or without the formation of "rice bodies." I have removed a large mass the size of an egg, due to tuberculous inflammation of the entensor tendons in front of the ankle. The long tumor, due to an effusion into one of these synovial sheaths, is often constricted where it passes beneath the annular ligament. Its long vertical shape helps to differentiate it from the more horizontal swelling of ankle-joint disease. Inflammation of the sheath of the tibialis posticus may extend to the ankle joint with which it is in close relation.

Beneath the extensor tendons one finds a *second layer of fascia* which separates them from the ankle joint and, farther forward, covers the extensor brevis digitorum muscle. The *dorsalis pedis artery* and the accompanying anterior tibial nerve lie *beneath this second layer* of fascia, which must be divided to reach them. In sprains, fractures, and dislocations of the ankle these synovial sheaths are apt to be torn and filled with effused blood, and the long-abiding stiffness after such injuries is in part due to these injuries of the sheaths and the resulting adhesions. Of the tendons about the ankle the *tendo Achillis and* the *peroneal tendons* are quite *subject to contracture,* the extensor tendons less so, and the tendons behind the internal malleolus still less. These contractures of the tendons lead to various deformities of position of the foot, known as club foot, and the affected tendons require division (tenotomy) to correct the deformity. The rupture and tenotomy of the tendo Achillis has already been described (p. 528). **The tibialis posticus tendon** *may be divided* (*a*) 5 cm. (2 in.) above the internal malleolus, which is just above its synovial sheath and where the tendon is farther from the artery than below. The knife is entered close to the inner border of the tibia. (*b*) It may be divided a little below and in front of the inner malleolus, between the internal annular ligament and the scaphoid bone. *The tibialis anticus may be divided* at the latter

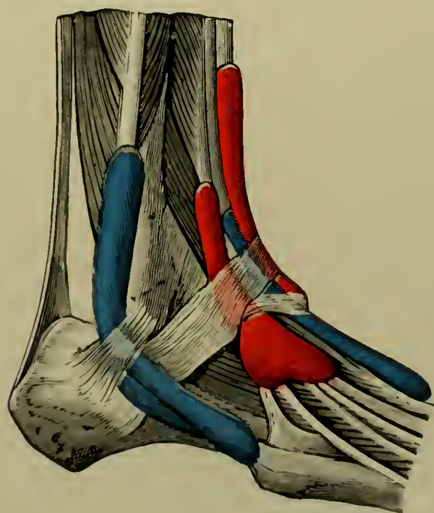
PLATE LVI

FIG. 183



The Internal Annular Ligament of the Ankle and the Artificially Distended Synovial Membranes of the Tendons which it Confines. (Gerrish, after Testut.)

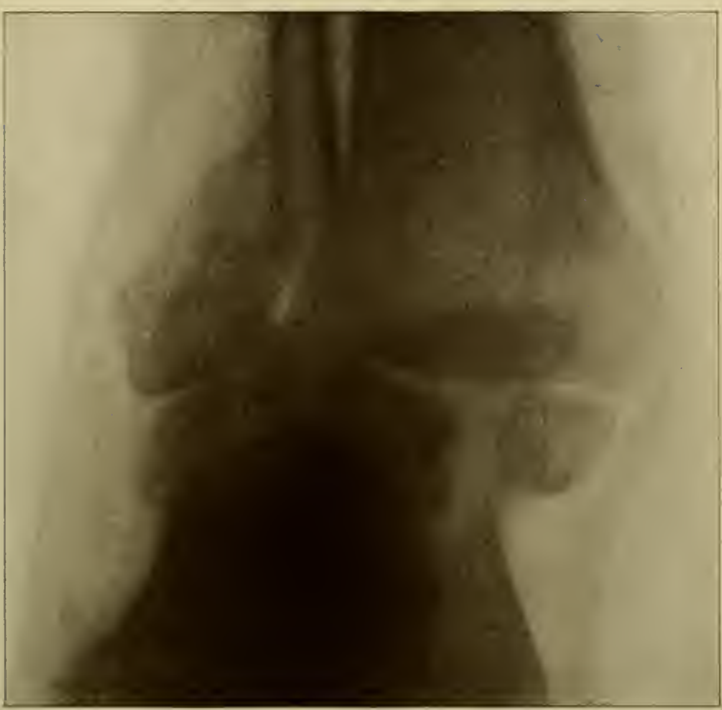
FIG. 184



The External Annular Ligament of the Ankle and the Artificially Distended Synovial Membranes of the Tendons which it Confines. (Gerrish, after Testut.)

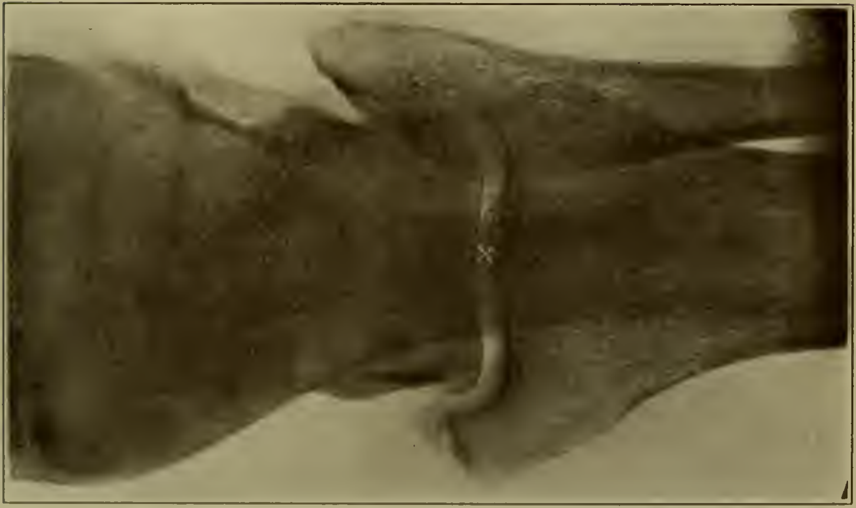
PLATE LVII

FIG. 185



Pott's Fracture by Abduction, two months after the injury.

FIG. 186



Left Ankle Joint. Anteroposterior cava somewhat from above.
Male, aged twenty-three years.

level with the posticus, or a little above its insertion into the internal cuneiform. The tendon of a paralyzed muscle may be joined to that of a sound one (*tendon grafting*) to prevent a deformity and restore certain movements of the foot. The tendons of the ankle are not infrequently ruptured through violence, especially the tendo Achillis.

Bursa.—A bursa is situated *between the tendo Achillis and the os calcis*, rising about 12 mm. ($\frac{1}{2}$ in.) above the latter. When inflamed it bulges on either side of the tendon, effacing the depressions which normally exist there. Such *inflammation, due to* excessive walking, an injury, or a badly fitting shoe, may simulate ankle-joint disease and, if suppurative, lead to caries of the os calcis. Pain is caused by flexion or extension of the foot or contraction of the calf muscles. Bursæ may develop from pressure over the malleoli, especially the external, as in tailors who sit cross-legged ("tailor's bursa").

The dorsalis pedis artery, from its superficial position, is frequently divided in wounds or ruptured in severe contusions, while the posterior tibial is well protected from injury by the prominent malleolus, the neighboring tendons, and the annular ligament. The *dorsalis pedis artery* may be *compressed* against the underlying bones and *its pulsation* may be sought for, to determine the condition of the artery and of the circulation, in senile gangrene and in suscepted embolism at the bifurcation of the popliteal.

The Ankle Joint.—The ankle joint *owes its strength to* the strength of the lateral ligaments and the many closely applied tendons, as well as to the mortise and tenon shape of the bony surfaces. The anterior and posterior ligaments are unimportant and so thin that *effusion*, when it occurs within the joint, is *first noticeable in front* as a fluctuating bulging, beneath the extensor tendons and especially on either side of them, in front of the malleoli. This bulging is the more marked because the synovial membrane forms somewhat of a pouch anteriorly and posteriorly. *The bulging in front of the external malleolus* is the *best point to open or inject* the joint. When the effusion is more marked it may be evident behind, as a bulging of the posterior part of the capsule, which gives rise to fluctuation on either side of the tendo Achillis.

The ankle joint proper is a true hinge joint and normally allows *no lateral motion*, except passively in extreme extension (plantar flexion) when the narrowest part of the upper surface of the astragalus is in the widest part of the tibiofibular mortise. The ankle should be *tested for lateral motion with the foot flexed* nearly to a right angle, care being taken to grasp the astragalus, and not the calcaneum, by the thumb and fingers directly below and in front of the two malleoli. If the foot is grasped a little lower, over the calcaneum, lateral motion is obtained between the astragalus and calcaneum. *Lateral movement* at the ankle joint *indicates disease or injury* of the joint. On account of its superficial and exposed position, *inflammation of the ankle joint* not uncommonly results from injury, exposure to cold and wet, etc. As the position of the joint does not affect its capacity, and the flexor and extensor muscles about balance one another, the foot does not assume

any characteristic position when the ankle is inflamed. Later the calf muscles aided by gravity and the pressure of the bedclothes induce plantar flexion, causing "pointing" of the toes.

Sprains of the ankle are common, as the weight of the whole body, acting through the leverage of the entire lower extremity in inversion or eversion of the ankle, tends to lacerate fibers of one of its lateral ligaments and strain some of the tendons. Landerer has expressed the opinion that 95 per cent. of so-called sprains are fractures. This is probably literally true if we count as fractures those cases where, instead of a tear of the ligament, a small portion of bone is avulsed at its attachment.

The *ankle joint* may be *dislocated* so that the *foot is displaced* backward, forward, inward, or outward. Only the anteroposterior forms are pure dislocations, the lateral forms being almost always associated with fracture of one or both bones of the leg at the ankle.

Dislocation of the Foot Backward.—Dislocation of the foot backward is usually *due to* extreme plantar flexion and the establishment of a new centre of motion between the posterior border of the tibial facet and the posterior lip of the astragalus, so that continued movement ruptures the lateral and anterior ligaments, and then the foot is pushed backward or the tibia forward as the plantar flexion is corrected. It may also be due to great force applied to either the foot or the leg while the other is fixed. It is resisted by (1) the shape of the upper articular facet of the astragalus and of the tibiofibular mortise, which are nearly one-fourth narrower behind than in front; (2) the increase of width from behind forward between the lateral facets of the astragalus; (3) the lower level of the articular surface of the tibia behind than in front; and (4) the re-inforcement of the posterior ligament by the flexor longus pollicis tendon. The foot appears shortened in front, where the lower end of the tibia projects prominently and rests upon the scaphoid and cuneiform bones, and the extensor tendons may be felt as tense cords. *The heel is lengthened,* exaggerating the depressions on the sides of the tendo Achillis, which curves markedly backward. As a result of fracture of the ankle by eversion, partial and even complete backward dislocations are not infrequent, but pure dislocations of this kind are rare. **Forward dislocation** is still more rare, for, though the anatomical factors which resist backward dislocation favor this form, the weight of the body or the external force and counterforce are rarely brought forcibly upon the ankle in the proper direction to produce it. The mode of production and the deformity of the foot are the reverse of the last variety.

Two forms of dislocation inward are observed: *In one the foot is much inverted,* so that the upper surface of the astragalus can be felt and seen as a prominence below the outer malleolus; in the other there is less or no inversion, but *the foot is much adducted,* so that the toes may even point directly inward. The latter form may be secondary to a backward dislocation. Many cases belong to the group of fractures of the ankle by inversion.

The so-called *outward dislocations* represent the deformity in cases of Pott's fracture (fracture by eversion).

Fractures of the Bones of the Leg just above the Ankle.—Fractures of the bones of the leg just above the ankle are *produced by eversion or inversion* of the foot, aided somewhat by the weight of the body. Both eversion and inversion produce fractures which are very similar. In reference to these fractures it should be remembered that the *tibia and fibula are very strongly bound together* at their inferior articulation, and that this point serves as the fulcrum of a lever for the fibula, of which the external malleolus represents the short arm and the fibula above the joint the long arm.

Fig. 187

Diagram of fracture by eversion of the ankle, showing the fractures of the two bones.

Fig. 188

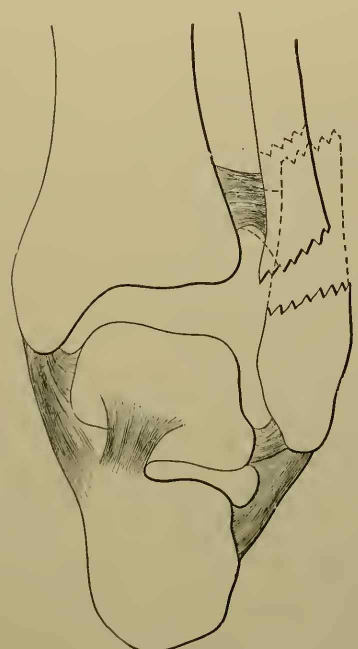


Diagram of fracture by inversion of the ankle. Fracture of the fibula only is represented and at two levels. The dotted lines show a fracture of the fibula some distance above the malleolus, the continuous lines a fracture at the base of the malleolus.

Fractures by Eversion and Abduction.—In fractures by eversion and abduction (Pott's fracture) (Fig. 187) the *strain first comes on the internal lateral ligament,* which may tear, but, owing to its strength, usually tears off the internal malleolus at its base. This *allows the further eversion* of the foot, and the astragalus then presses the external

malleolus outward. This is resisted by the strong ligaments of the inferior tibiofibular joint, which suffer violence in the shape of partial rupture or sprain, but usually hold the bones together, so that the strain comes upon the long arm of the lever, the *shaft of the fibula, which breaks* 2.5 to 7.5 cm. (1 to 3 in.) above the malleolus. The upper end of the lower fragment of the fibula is displaced toward the tibia. The foot, with the outer malleolus, is displaced outward, and often somewhat backward, and everted, the inner malleolus, or the lower end of the fractured tibia, is very prominent and may cause the laceration of the taut overlying skin. **The characteristic features are** (1) *lateral mobility,* due to the essential lesion, the tibiofibular diastasis, and the consequent widening of the mortise, and to the fracture of the internal malleolus and of the fibula above its malleolus; and (2) *three points of tenderness*—(*a*) in front of the tibiofibular joint, in the groove between the tibia and the external malleolus, (*b*) over the base or anterior border of the internal malleolus, and (*c*) over the fibula just above the malleolus, or 2.5 to 5 cm. (1 to 2 in.) higher.

In fractures due to forcible inversion (Fig. 188) the external lateral ligament first feels the strain. If simply the ligament partly gives way *a sprain* may result, unless the action of the force continues. If the ligament holds, and it commonly does, it pulls the tip of the external malleolus inward, which forces the long arm of the fibular lever outward, until it breaks close above the malleolus, or still higher, or at the epiphyseal line in the young. The force continuing inverts the foot still farther and the astragalus presses against the internal malleolus and breaks off the latter or a larger portion of the lower end of the tibia, the line of fracture passing obliquely upward and inward through the tibia from its articular surface. The *lateral mobility and the three points of tenderness* are present in this form, but perhaps not so markedly, as there is less and may be no injury at the lower tibiofibular joint. In this form the injury may stop short with fracture of the fibula, no injury of the internal malleolus or internal ligament resulting. In fractures by inversion the upper end of the lower fragment of the fibula is displaced outward, unless it is held by the untorn periosteum. To determine the presence and the point of fracture of the fibula an excellent way is to press inward on the tip of the malleolus, the short arm of the lever, which forces the upper end of the lower fragment to tilt outward and causes a false point of motion, or at least a point of tenderness, to appear at this point.

Owing to the frequency of these two classes of fractures and the disability following improper treatment, they should be carefully reduced and treated. It is especially important to correct the lateral displacement and the eversion, otherwise the gait is painful and imperfect, for the weight of the body then falls too far to the inner side of the foot, so that a strain is brought upon the internal lateral ligament and a painful flat foot is produced. If the posterior displacement is not corrected, dorsal flexion at the ankle is limited and the patient must toe far outward in walking to avoid the necessity of dorsal flexion.

The *lower epiphysis of the tibia* is more often *separated* than the upper.

The fibula is usually broken at the same time at a higher level, though its epiphysis, which reaches to the level of the tibial articular surface, is sometimes separated in place of a fracture of the shaft. The lower epiphysis of the tibia *includes* the malleolus and the articular surface, and *unites* in the nineteenth year; the *lower epiphysis of the fibula includes* the outer malleolus to the upper limit of its articular facet for the astragalus, and unites about the twenty-first year. Both epiphyseal lines are horizontal and are in close relation mesially with the synovial membrane, which extends up between the two bones. They are separated from the synovial membrane by the periosteum, which continues over them, so that the membrane usually escapes injury. Arrest of growth of the tibia may occur and this is followed by inversion of the foot, on account of overgrowth of the fibula.

Excision of the ankle is rarely done for injury and not often for tuberculous disease. Symes' or Pirogoff's amputation often gives a better result. **Arthrectomy** often gives good results. *Bilateral incisions* are usually made over the front of the malleoli; curving forward over the foot in such a way as to lie between the tendons in front and those behind the malleoli. König chisels away the attachments of the lateral ligaments to the malleoli to spare the ligaments. Removal of the astragalus greatly facilitates the free access to all parts of the joint and a thorough arthrectomy. In such cases it is better to divide the ligaments and spare the malleoli, especially in young subjects, owing to the proximity of the latter to the epiphyseal lines. Lauenstein uses a single long external incision, Kocher a curved oblique external incision, and both of the latter then retract the peroneal tendons backward, divide the external lateral ligaments, and fully supinate (invert) the foot, so as to expose both articular surfaces.

THE FOOT.

Landmarks and Surface Markings.—*Along the outer border* of the foot nearly the entire outer surface of the *calcaneum is* subcutaneous, and we can feel its external tubercle and its peroneal tubercle, the latter less than 2.5 cm. (1 in.) below and a little in front of the tip of the malleolus. The short peroneal tendon is above, the long one below it. Midway between it and the external malleolus is the calcaneo-astragaloid joint. The *tuberosity* of the *base of the fifth metatarsal bone* is the most prominent landmark on this border, and can be felt under all conditions of swelling, etc., about 6 cm. (2½ in.) in front of the malleolus. The cuboid extends for 2.5 cm. (1 in.) or so behind it, hence the calcaneocuboid (mediotarsal) joint is a little more than midway between the tip of the external malleolus and the tubercle of the fifth metatarsal. *Along the inner border* of the foot we can feel the internal tubercle of the calcaneum; the sustentaculum tali, 2.5 cm. (1 in.) below the internal malleolus; the head of the astragalus, prominent in flat foot, 12 to 18 mm. (½ to ¾ in.) in front of the sustentaculum; *the tuberosity of the scaphoid*, about 3 cm. (1¼ in.) in front of the susten-

taculum, the space between the two being occupied by the inferior calcaneoscaphoid ligament and the tibialis posticus tendon; the base and head of the first metatarsal bone, and the sesamoid bones on the plantar surface of the latter. The calcaneo-astragaloid joint lies directly above the sustentaculum, and the first metatarsophalangeal joint a little distal to the middle of the ball of the great toe. The tuberosity of the scaphoid is *the best landmark* on the inner border, and can be felt even when the foot is much swollen. In such conditions the head of the metatarsal bone is not plainly palpable, hence it is well to know that the *first tarsometatarsal articulation* is 3.5 cm. ($1\frac{1}{2}$ in.) in front of the tuberosity of the scaphoid and 2 cm. ($\frac{4}{5}$ in.) in front of the line drawn transversely across the foot from the tubercle of the base of the fifth metatarsal bone, or the fifth tarsometatarsal articulation.

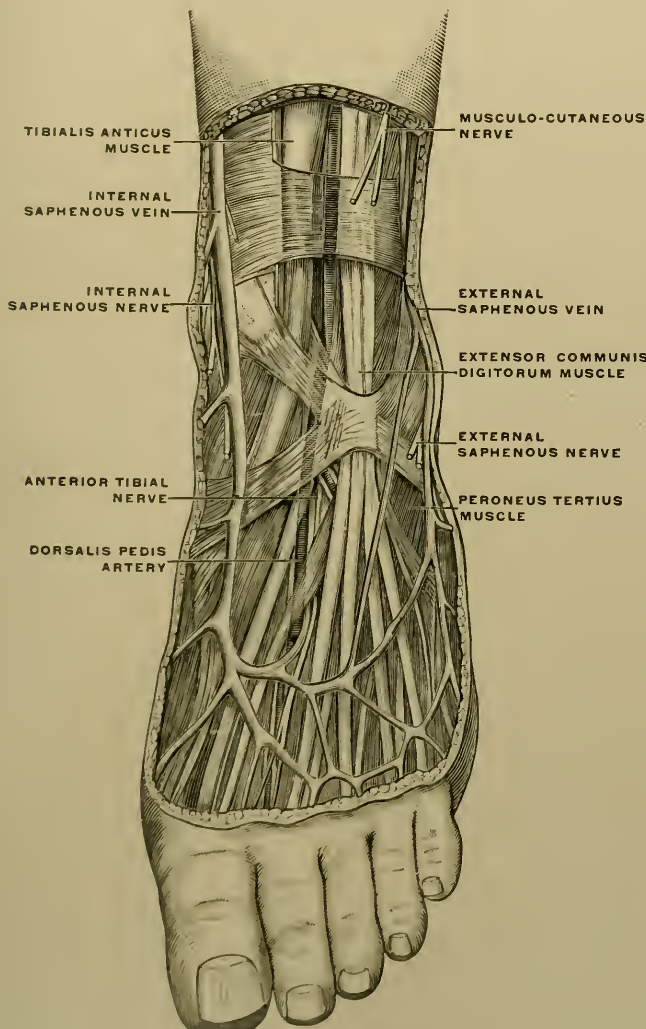
Topography.—The mediotarsal joint, *i. e.*, the joint between the astragalus and calcaneum posteriorly and the scaphoid and cuboid anteriorly, *commences* internally just behind the scaphoid tuberosity and externally a little anterior to the mid-point between the tip of the external malleous and the tubercle of the fifth metatarsal bone. The *joint* line is transverse with a slight sinuosity, convex forward internally and concave forward externally. The position of the first tarsometatarsal joint has already been indicated, that of the fifth lies just behind the prominent tubercle of the fifth metatarsal bone. The *tarsometatarsal joint line*, between these two ends, is *interrupted* by the mortising of the second metatarsal bone between the internal and external cuneiform bones. The line of its articulation with the middle cuneiform is 1 cm. ($\frac{2}{5}$ in.) behind that of the first tarsometatarsal joint. The *metatarsophalangeal articulations* are about 2.5 cm. (1 in.) behind the webs between the corresponding toes, the proximal and part of the middle phalanges being buried in the web.

On the outer part of the *dorsum* of the foot the fleshy mass of the *extensor brevis digitorum* can be felt beneath the tendons of the extensor longus digitorum, where it can be seen when in action. It fills the gap between the front of the astragalus and the calcaneum. The course of the dorsalis pedis artery has been given above (see p. 532); it is crossed by the inner tendon of the extensor brevis muscle, and rests on the head of the astragalus, the dorsum of the scaphoid, and the interval between the middle and internal cuneiform bones.

The plantar arteries start at the bifurcation of the posterior tibial, midway between the inner malleolus and the inner border of the heel. Thence the smaller branch, *the internal plantar, follows a line* to the middle of the plantar surface of the great toe. *The course of the external plantar* is obliquely across the sole to a point a little internal to the base of the fifth metatarsal bone, and thence obliquely inward across the bases of the metatarsal bones, which are covered by the interossei, to the proximal end of the first interosseous space, where *its arch is completed* by anastomosing with the communicating branch of the dorsalis pedis. By means of this arch the anterior and posterior tibial arteries anastomose. In *wounds of the plantar arch*, which are serious on

account of its depth beneath many important structures, the ligature of both tibial vessels, at or just above the ankle, would not arrest the hemorrhage without fail, for the peroneal artery would bring blood to the arch through (1) the anastomosis of the anterior peroneal with the

Fig. 189



Dorsal view of foot and ankle.

external plantar artery, (2) the anastomosis of the posterior peroneal with the internal calcaneal branch of the posterior tibial, and (3) the anastomoses of both of these peroneal branches with the tarsal and metatarsal branches of the dorsalis pedis. In fact, however, elevation and pressure will check most hemorrhages of the foot.

The Skin.—The skin of the dorsum and inner aspect of the foot is thin and movable, that of the sole is dense and thick where it normally comes in contact with the ground, *i. e.*, under the heel, the outer border, and the distal ends of the metatarsal bones. The skin on the dorsum is readily excoriated, and the lack of fatty tissue or muscle between it and the skeleton of the foot makes it very liable to gangrene from the pressure of splints, dressings, etc., or from contusions. The skin of the foot becomes *thick and callous* wherever it is exposed to undue pressure, and the callosities often become painful when pressed upon. Beneath the abnormal thickenings *bursæ* may develop.

The subcutaneous tissue on the dorsum is lax and abundant, so that great swelling occurs from inflammation; and edema and general dropsy are often first evident here. This tissue is very *thick and dense on the sole,* connecting the skin closely with the fascia and *enclosing the fat in little spaces,* as in the palm and the scalp. Hence the *skin of the sole does not gape* on being incised, so that exploratory incisions must be longer than otherwise and strongly retracted, to expose foreign bodies, etc. It is most abundant on those parts of the sole where the pressure is greatest, and in those who walk most, and may even reach 2 cm. in thickness beneath the heel, so that it forms a veritable cushion that must diminish the effect of contusions and falls. Owing to its density *inflammation* in it extends with difficulty and can *produce little swelling but much pain,* especially as the skin of the sole is well supplied with nerves and is very sensitive, much more so than that of the dorsum.

In the subcutaneous tissue on the dorsum many *superficial veins* are visible. They *form an arch,* concave toward the ankle, from the ends or sides of which the internal and external saphenous veins arise. In varicose veins of the leg these veins of the dorsum are often involved. The internal and external saphenous and the musculocutaneous nerves are in the same subcutaneous layer. "*Perforating ulcer,*" a peculiar affection, occurs generally at the points of pressure on the sole, and is often attributed to arteriosclerosis, diabetes, or trophic disturbances in certain nerve lesions, like locomotor ataxia, etc. *It appears* usually *as a sinus* leading to bone, into a joint, or through to the dorsum, and often heals with rest. After healing all pressure must be removed from the scar of the "ulcer."

The Fascia of the Dorsum.—The fascia of the dorsum consists of *two layers;* the more superficial one is continuous with the annular ligaments and covers the long tendons; the deeper forms a sheath for the extensor brevis muscle and covers the dorsalis pedis artery. They are thin and of no surgical importance. On the contrary, **the deep fascia of the sole or plantar fascia** is very important and, like the palmar fascia, *consists of three parts,* a dense strong central portion and two thinner lateral portions. **The outer portion** is, however, very strong and forms a firm band between the calcaneum and the fifth metatarsal bone. **The central portion** is stretched like a bowstring between the two ends of the longitudinal arch of the foot, the inner tuberosity of the calcaneum, and the heads of the metatarsal bones, where it divides into slips for the

toes similar to those for the fingers in the hand. Hence the plantar fascia, especially its central portion, is an *important factor in maintaining the longitudinal arch* of the foot, the sinking of which, in flat foot, necessitates a marked yielding of this fascia. *Talipes cavus,* in which the arch is much raised, *depends* largely or entirely *upon a contraction of this fascia.* In this condition and in talipes varus, in which this fascia is often contracted and the arch correspondingly raised, the *fascia is divided subcutaneously by a tenotome* to cure the deformity. This division is *best made* about 2.5 cm. (1 in.) in front of its posterior attachment to the internal calcaneal tuberosity, in its narrowest part, where the knife, entered from the inner side, is behind the external plantar artery. This fascia bears the same relation to *inflammation and abscess* as the palmar fascia in the hand, resisting their extension toward the sole. Similarly *two intermuscular septa* pass from its deep surface, where it joins the lateral portions, to the plantar aspect of the bones and the interosseous fascia. *Three muscular compartments* are thus formed, of which the central one is the larger and deeper and contains the majority of the muscles and tendons and the plantar vessels and nerves. These intermuscular septa are too feeble to affect the course of a deep plantar abscess to any great extent.

The Posterior Tibial Nerve.—The posterior tibial nerve bifurcates a little above the division of the artery. The internal plantar nerve, unlike the corresponding artery, is the larger of the two. *In its distribution the internal plantar nerve* corresponds closely with that of the median in the hand, the *external plantar* with the ulnar.

The Bursa.—The bursa in the subcutaneous tissue over the first metatarsophalangeal joint, when enlarged, constitutes **a bunion.** This is usually associated with a deformity of the great toe (*hallux valgus*), generally due to improperly shaped or too short shoes, which force the great toe outward and render its metatarsophalangeal joint very prominent internally. The internal lateral ligament becomes lengthened and the overlying skin becomes thickened and indurated, and the bursa, pressed between this thickening and the projecting bone, often *becomes inflamed.* If it suppurates it often opens both superficially and into the joint, which latter then becomes disorganized and requires resection. Resection is also employed to cure the deformity and the resulting bunion. In this operation it must be remembered that the outwardly displaced extensor tendon of the toe and the outer part of the fibrous capsule of the joint have probably both become contracted and shortened. There is often a considerable overgrowth of the distal end of the metatarsal bone on its inner side, which must be removed to straighten the toe. Flat foot tends to produce a bunion by pressure upon this joint. This same joint is selected with singular unanimity as the sole or principal site of the manifestation of gout. This is partly owing to the abundant fibrous tissue at a point where the circulation is slight and sluggish, where a good part of the weight is borne, and which is often exposed to cold and damp. Holden describes the frequent occurrence of a large irregular bursa between the tendons of the extensor

longus digitorum and the underlying prominent head of the astragalus, which sometimes communicates with the mediotarsal joint. *Bursæ* may develop almost anywhere *from pressure,* as over the points on which the foot rests in the various forms of club foot, especially over the cuboid in talipes equinovarus.

The numerous **fine lymphatics of the sole** pass to the borders of the foot, especially the inner border, and to the dorsum, where the main lymph vessels are found, particularly on its inner side. Thence they run along the inner side of the leg with the internal saphenous vein, and *pass mostly to the inguinal nodes.* Some from beneath the heel and from the posterior half of the outer border of the foot run up the posterior surface of the leg, with the short saphenous vein, and *enter the popliteal nodes.* Hence in inflammation on the dorsum and inner border of the foot lymphatic enlargement will involve the inguinal nodes, while inflammation on the outer border may affect either the inguinal or popliteal nodes, or both. Lymphangitis most often follows lesions of the dorsum and inner border.

The foot is arched in two directions, longitudinally and transversely. *These arches are due to* the shape of the bones, and are *maintained by* ligaments and, to a less extent, by the tendons and short muscles of the sole. They account for the strength of the foot and its relative freedom from injury, though constantly exposed to traumatism.

The Longitudinal Arch.—The longitudinal arch, the more important of the two, *consists of two piers,* on the ends of which the foot rests, *i. e.,* the heel and the heads of the metatarsal bones. In addition, the foot is steadied or *buttressed by its outer border,* which broadens the surface of contact with the ground. The middle of the inner border and the inner part of the sole are raised from the ground by the inner and more curved portion of the arch, which is thus known as the *instep.* On account of this difference of the two borders the arch is *divided into two parts* having a *common posterior pillar,* the calcaneum and the hind part of the astragalus. *The anterior pillar* of the outer and flatter arch is formed by the cuboid and the two outer metatarsals; the anterior pillar of the inner and more curved arch is formed by the head and neck of the astragalus, the scaphoid, cuneiform, and three inner metatarsals. The inner division of the arch bears most of the weight, the outer division steadies the foot. The *anterior pillars,* composed of a number of small bones and their joints, are *very elastic and springy,* giving the elasticity to the gait. *The posterior pillar,* consisting of only two bones, astragalus and calcaneum, and one joint of very limited motion, *is solid* in order to support the greater part of the weight of the body, *and inelastic* to give a firm attachment and leverage to the calf muscles, which elevate this pillar. The difference in the two pillars is seen in jumping from a height. When we alight on the heels the jar is felt throughout the body, but when we alight on the ball of the foot the elasticity of the anterior pillar of the arch absorbs, so to speak, all the jar. *The astragalus,* or more especially its head, serves as *the keystone of the arch,* but, unlike keystones in ordinary arches, it is not wedge-shaped,

it is mobile and it only imperfectly supports and receives support from the two pillars.

The Transverse Arch.—The transverse arch is most marked near the tarsometatarsal joints and *is due to* the wedge shape of the bones. It is continued with diminished curvature to the heads of the metatarsal bones. *It protects* the vessels and soft parts of the sole from injurious pressure and, by its yielding in walking, etc., gives elasticity and spring to the foot.

Both of the arches are maintained by ligaments and tendons. **The transverse arch is maintained** *by* the transversely directed dorsal, plantar, and interosseous ligaments, and by the obliquely directed peroneus longus tendon and, to some extent, the expansion of the tibialis posticus tendon, which pull against each other from opposite sides. The latter tendon also helps to maintain the longitudinal arch. When the transverse arch is properly maintained the anterior pillar of the longitudinal arch rests upon the heads of the first and fourth metatarsal bones only; that of the fifth also presses upon the ground in many cases, especially when more weight is borne on the foot. If the transverse arch yields, the heads of the intervening metatarsal bones receive undue pressure and callosities develop over them. **The longitudinal arch is maintained** *principally by* the inferior ligaments of the mediotarsal joint, the long and short plantar and the inferior calcaneoscaphoid ligaments. The former are the main support of the outer, firmer, and less elastic part of the arch; the latter is known as the "*spring ligament,*" as it is the principal ligament that supports the inner and more springy part of the arch. *It helps to support the head of the astragalus,* part of which rests directly upon it. It in turn is *supported by the tibialis posticus tendon,* which runs in a groove on its under surface and comes into action when the heel is raised and the weight is thrown onto the instep, and therefore when the most strain comes on this ligament in supporting the head of the astragalus and the mediotarsal joint. The short muscles to the toes arising from the calcaneum also help to maintain this arch. The tibialis anticus is said to support the keystone, but as no keystone can be supported, but only weakened, by traction from above, it can only support it by reason of the fact that the constituents of the arch are connected and supported by ligaments.

Club Foot.—*The longitudinal arch sometimes* yields and *flattens out.* This gives rise to one variety of club foot known as "**flat foot,**" in which *the foot is pronated* (everted), *the fore foot is abducted, the sole becomes flat,* and the patient walks mainly on the inner side of the foot. Some abduction of the foot is necessarily associated anatomically with raising of the outer border, or pronation, for the pronating peronei are also abductors. In flat foot the impression of the wet sole on a sheet of paper shows no deep concavity along the inner border, as normally, but rather a convexity (see Fig. 190). *It occurs* particularly in those who stand a great deal and especially in adolescents whose ankles may be originally defective, who are below par, who have grown rapidly, and in whom the muscles, ligaments, and fasciæ are weakened, relaxed, and

more ready to yield to long-continued pressure. *The inferior calcaneo-scaphoid ligament suffers most,* and, when the tibialis posticus fails support, it yields and allows the weight of the body to press the head of the astragalus downward, forward, and inward, so that the latter, together with the depressed sustentaculum tali and the scaphoid tuberosity, form prominences on the inner border of the foot, which may rest on the ground. They may even form the main points of support along the inner border. The plantar and deltoid ligaments and the plantar fascia also yield, and in time the deformity may be rendered permanent by alterations in the shape of the bones, by contraction of the ligaments that are relaxed, and by shortening of the peronei muscles, which are relaxed by the abduction and eversion of the foot. In the acquired deformity, occurring in the developed foot of adolescents or adults, the affected tarsal bones and articulations suffer abnormal pressure or stretching, which often causes severe pain. The latter gives rise to the term "*painful flat foot,*" to distinguish it from a similar deformity without

Fig. 190

Flat foot. Normal foot.

pain, which may be congenital. The acquired deformity is also known as *acquired talipes valgus,* the congenital as *congenital talipes valgus.* The latter is usually associated with some talipes calcaneus.

The normal foot is not flat at birth. Some depression of the astragalus and prominence of the internal malleolus may be seen in a normal foot when the entire weight of the body is borne on it. Flat foot is not uncommon in connection with genu valgum, for the weight descends to the inner side of the heel and hence is transmitted to the astragalus somewhat from without inward. It may also result from a Pott's fracture in which the eversion is not sufficiently corrected.

Talipes.—Talipes is a term *applied to all forms of club foot,* of which there are *four primary varieties* which may be variously combined with one another. **In talipes equinus** the heel is drawn up by the contraction of the calf muscles so that *the patient walks on the balls of the toes. The arch* of the foot is *often exaggerated,* and the mediotarsal joint is in marked plantar flexion. Talipes equinus is rarely congenital, and *results from* infantile paralysis of the extensor tendons and other paralytic lesions,

as well as from the long-continued extended position of the foot, due to faulty splints or the weight of the bedclothes in cases of long illness, etc.

The opposite condition, **talipes calcaneus**, is *characterized by* dorsal flexion, and is *due to* contraction of the anterior muscles, usually associated with infantile paralysis of the posterior groups. The patient walks on the heel with the foot drawn up. It is rarely congenital and often combined with talipes valgus and pes cavus.

In **talipes varus** *the foot is inverted* and hence *also adducted,* for the same muscles produce both actions. It rarely occurs without some talipes equinus, and *talipes equinovarus or* **congenital club foot** is *the commonest form of club foot.* It usually originates in *an arrest of the fetal development* of the feet, resulting in the delayed rotation of the feet and legs, so that the equinovarus position of the feet that is normal in early fetal life persists. A similar deformity may result from infantile paralysis of the extensor and peronei muscles, which resist plantar flexion and adduction of the foot. In the congenital form the opposing calf muscles, flexors and adductors, become contracted, resisting the correction of the deformity and gradually increasing it. The deformity is a kind of dislocation inward of the fore part of the foot at the mediotarsal joint, and consists of elevation of the heel, inversion and adduction of the foot, and exaggeration of its longitudinal arch, associated with contracture of the plantar fascia. Hence *the patient walks on* the outside or, in extreme cases, even on the dorsum of the foot. The toes point inward, so that one foot is lifted over the other in walking. The os calcis becomes more vertical than horizontal; the astragalus is tipped downward in front, so that the fore part of its articular surface projects under the skin and only its posterior part articulates with the tibia, and its elongated neck is bent inward and downward; the atrophied scaphoid, with the three cuneiform bones, are displaced inward and backward, near the inner malleolus; and the cuboid, displaced upward and inward, may become the chief point on which the foot rests and the weight is borne. The tarsal bones become much misshapen. The *neck of the astragalus* is deflected inward from the axis of its body, on an average, at an angle of 12.32 degrees in the adult, 35.76 degrees at birth (Scudder), and 50 degrees in talipes equinovarus. The ligaments are contracted on the concave inner side and stretched on the other side. The peroneus longus tendon may slip in front of the external malleolus. In many cases of club foot the contracted muscles require tenotomy, also the plantar fascia when that is contracted.

The **chief joints** of the foot are the calcaneo-astragaloid, the mediotarsal, and the tarsometatarsal.

The *principal ligament* of the calcaneo-astragaloid joints, from a surgical standpoint, is the massive *interosseous ligament* in the sinus pedis. The lateral ligaments of the ankle, the surrounding tendons the various calcaneo-astragaloid and the external calcaneoscaphoid ligaments help to hold the bones together. This is a double joint, the posterior having a separate synovial sac, the anterior a sac in common with the astragaloscaphoid joint. The *movements* of ab- and adduc-

tion and some pro- and supination are allowed. This joint is of practical interest in subastragaloid amputation, subastragaloid dislocation, dislocation of the astragalus, and resection of the astragalus.

Subastragaloid Dislocation.—Subastragaloid dislocation involves the astragaloscaphoid and calcaneo-astragaloid joints. The position and relation of the astragalus with the tibia and fibula and the movements in the ankle joint remain normal. In these dislocations the *foot is displaced* either (1) inward, or rather inward and backward, or (2) outward, very rarely (3) backward or (4) forward. The reason of this is to be found in the direction of the opposed surfaces of the calcaneum and scaphoid, which slant from above and behind downward and forward. Hence dislocation forward of the foot is very rare (2 cases reported). The rounded head of the astragalus offers little resistance to lateral or backward and inward movement of the scaphoid and displacement of the foot, but it may help to account for the rare occurrence of complete backward dislocations. The two forms (1) and (2) are about equally common. Were it not for the resistance offered by the projecting sustentaculum tali and the outward obliquity of the posterior articular process of the calcaneum, outward displacement of the foot would be the more common, for the weight of the body is transmitted to the astragalus in such an inward direction as would tend to displace it inward and the foot outward.

In the **dislocation inward and backward** the dorsum is shortened, the heel lengthened, the foot adducted and supinated, the external malleolus and the head of the astragalus are very prominent on the outer side of the dorsum, and the internal malleolus is deeply buried. *The deformity* resembles talipes varus. *The cause* is often forcible inversion and adduction of the foot, usually from a fall from a height. In the **outward dislocation** either the outward displacement may be *combined with marked abduction* of the toes, when the foot turns on the posterior calcaneo-scaphoid joint, if the bones have not separated there, *or the foot may be displaced bodily outward.* Hence the dislocation may be incomplete as regards the posterior calcaneo-astragaloid joint. When the foot is abducted there is more or less eversion and the head of the astragalus is very prominent on the inner side. In the form with simple outward displacement the inner malleolus is very prominent and approaches the level of the sole. The head of the astragalus projects below and in front of it, while the outer malleolus is buried in the depression above the prominence of the outer surface of the calcaneum and cuboid. The interosseous calcaneo-astragaloid, the astragaloscaphoid, and one of the lateral ligaments of the ankle are commonly torn. Subastragaloid dislocations are *often compounded.*

Dislocation of the Astragalus.—Dislocation of the astragalus is a combination of the subastragaloid dislocation and that of the ankle, and is much more frequent than either of them. It is *often compound,* and either or both *malleoli may be fractured.* The astragalus may be *displaced* anteroposteriorly or laterally. Dislocation outward and forward is the commonest form, inward and forward the next, directly

forward or backward are rare, and inward is almost unknown. In the **dislocation outward and forward** the head of the astragalus rests on the cuboid and external cuneiform, and is freely movable. *The foot* is adducted, inverted, and usually displaced inward, so that the internal malleolus is buried, the external is prominent. In the **inward and forward dislocation** the head of the astragalus projects below and in front of the inner malleolus, and is much depressed, as if rotated on a transverse axis. *The foot* is usually everted and abducted, but sometimes simply displaced outward.

The malleoli are brought nearer the sole in almost all cases of dislocation of the astragalus. In addition to the above forms of displacement, *the astragalus,* while remaining within the tibiofibular mortise, *may rotate* on its anteroposterior axis, sometimes on its vertical axis. If reduction under anesthesia or by open operation fails, excision of the astragalus should be done. *Dislocation of* one or more of the *other tarsal and of the metatarsal bones* occasionally occurs, the most frequent being dislocations of the scaphoid, the inner cuneiform, or the first metatarsal. The latter is usually displaced upward.

The Mediotarsal Joint.—The mediotarsal joint, *composed of* the astragaloscaphoid and calcaneocuboid joints, is *the most movable of the tarsal joints and permits* ab- and adduction, pro- and supination, and flexion and extension of the fore part of the foot on the back part. Flexion in these joints is simultaneous with extension of the ankle, and vice versa. In these movements *flexion is combined with* adduction and supination of the foot, *extension with* abduction and pronation of the foot, owing to the obliquity of the axis of this joint, from within outward and somewhat backward and downward. This combination is seen in talipes varus and valgus, in which, as well as in pes cavus and pes planus, the principal displacement occurs in the mediotarsal joint. In studying the arches of the foot we have seen that *the inferior ligaments of this joint* (the inferior calcaneoscaphoid and the plantar ligaments) are *the principal support of the longitudinal arch.* Injury at the mediotarsal joint is usually avoided by the elasticity of the anterior pillar of the arch of the foot.

Exclusive of that of the ankle, there are *six synovial membranes* among the joints of the tarsus and sometimes seven, if there is a separate sac between the cuboid and external cuneiform. *The most extensive* is that between the scaphoid and the three cuneiform bones, which extends forward between the latter to the second and third tarsometatarsal joints and the joints between the second and third and third and fourth metatarsal bones. Hence disease of the bones in relation to this sac would be most likely to extend, while that of the bones near the posterior calcaneo-astragaloid joint would be least likely to do so.

Through each of *the three principal joints* of the foot that we have named, *amputation may be practised.* In **subastragaloid amputation** the astragalus is disarticulated from the calcaneum and the scaphoid and *two synovial sacs are opened.* The extremity rests on the astragalus and the operation gives a good result. The stump is longer, broader, and more

thickly padded than that after Symes' amputation. The end of the stump is liable to be pulled up and back by the tendo Achillis taking on a firm attachment (Farabeuf). In **Chopart's amputation** *through the mediotarsal joint* two synovial sacs are opened. Subsequently, from contraction of some muscles or loss of the point of attachment of their antagonists, *the heel may be drawn up* by the calf muscles so that the scar on the anterior face is turned downward, or the inner border of the stump may be raised so that it rests on the outer border. It is not well suited to cases of bone disease, and the operation is now seldom practised. The landmarks have been given for **Lisfranc's amputation** *through the tarsometatarsal joint* and *the only difficulty* pointed out, *i. e.*, the backward projection of the second metatarsal bone between the outer and inner cuneiform bones, where its chief bond of union with the tarsus is the interosseous ligament that connects it with the inner cuneiform. **Hey's operation** *avoids the difficulty* of disarticulat ng this bone by sawing through it, in the line of the other joints. Neither operation is often indicated or even possible in conditions depending on accident or disease.

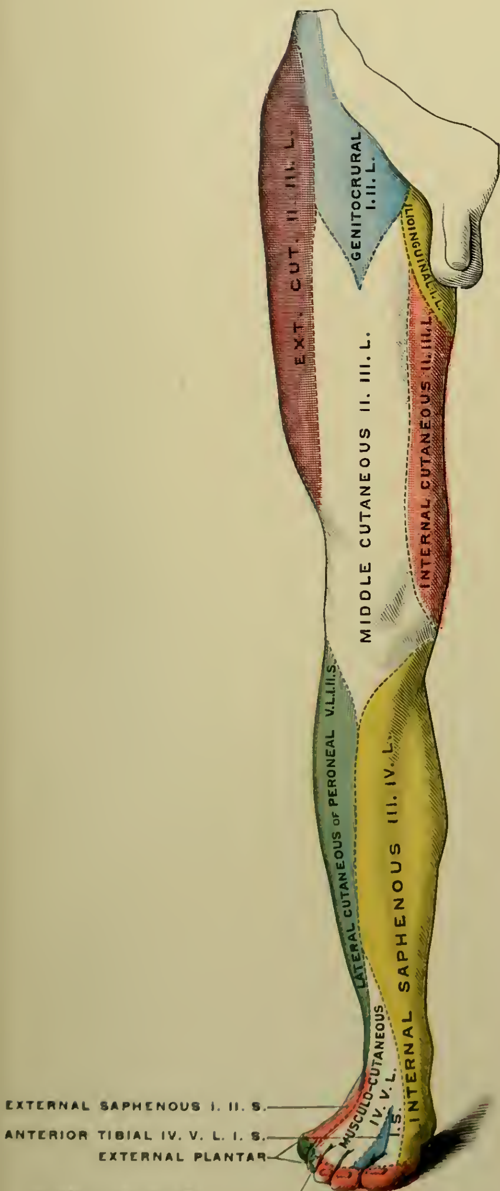
Far better than Chopart's amputation are the two following amputations of the foot. In **Symes' amputation** *the incision* runs from the tip of the outer malleolus vertically downward, then transversely across the sole and vertically up on the inner side to 12 mm. ($\frac{1}{2}$ in.) below the inner malleolus. This brings the end of the inner incision at the same height as the external. The soft parts covering the heel are dissected carefully away from the calcaneum, and *the tough skin of the heel,* accustomed to bearing pressure, *covers the stump* left by sawing the leg bones just above the articular cartilages. The skin of the inner part of the heel flap is supplied by the internal calcaneal branch of the posterior tibial artery and the calcaneal branches of the external plantar artery, and it is most important for the life of the flap not to cut off this blood supply, as may be done by carrying the internal limb of the incision farther back than directed.

Pirogoff's amputation closely resembles Symes' except that *the incision* is carried *a little farther forward; the calcaneum is sawed through* in the line of incision, or more obliquely (from above downward and forward); the sawed surface of the posterior segment of the calcaneum is applied to the under sawed surface of the tibia; the astragalus is removed with the foot; and the tendo Achillis is not divided. Owing to the position of the incision, *the plantar vessels are divided farther forward* than in Symes' operation, so that there is less danger of gangrene of the skin on the inner side of the heel. In **amputation of the great toe** the large size of the head of the first metatarsal bone must be borne in mind, so as to cut the flaps large enough to cover it and bring the line of the cicatrix above the plantar surface, for, as it is one of the anterior ends of the longitudinal arch, this surface is subject to much pressure.

Morton's metatarsalgia has been thought (Morton) to be due to the pinching of branches of the external plantar nerve between the head and neck of the fourth metatarsal bone and the bony prominences of the fifth metatarsophalangeal joint. It is probably often due, however, to the

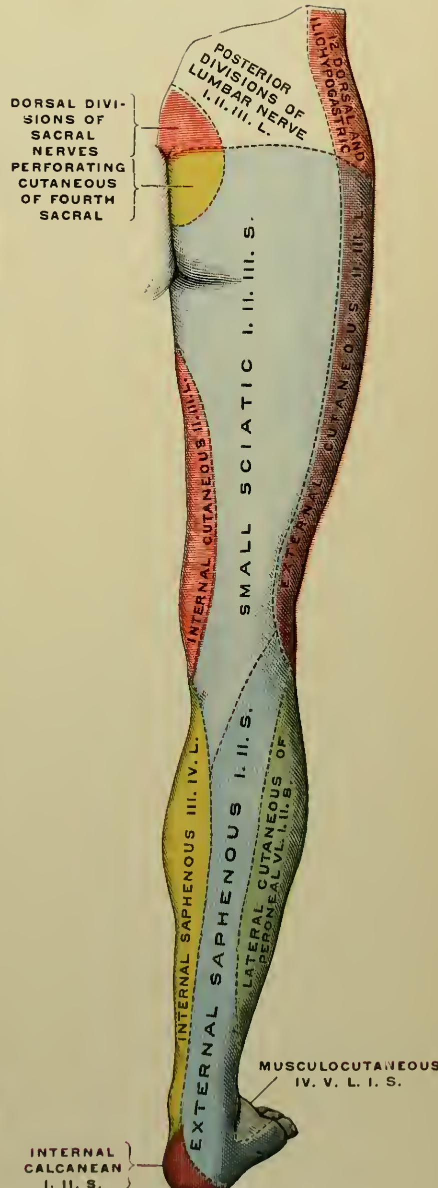
PLATE LVIII

FIG. 191



Areas of Distribution of Cutaneous Nerves of the Front of the Lower Limb. (W. Keiller, after Testut.)

FIG. 192



Areas of Distribution of Cutaneous Nerves of the Back of the Lower Limb. (Testut.)

compression of a communicating branch between the fourth division of the internal plantar and the external plantar between the head of the fourth metatarsal and the ground (R. Jones). The fact that this affection is usually associated with collapse of the transverse arch, which increases the pressure on the parts beneath, and the situation of the digital nerves, superficial to or beneath and not between the bones, supports this view. It is a painful affection occurring at the base of the fourth (or third and fourth) toe of adults, most often in women.

The calcaneum is more often **fractured** than any of the tarsal bones. By a fall on the heel it may be splintered and crushed, especially in its anterior half, and its vertical diameter may be decreased, so that the sole is flattened and the malleoli are approximated to it. By a forcible contraction of the calf muscles the calcaneum has occasionally been fractured, always behind the astragalus and sometimes only the hind part, which attaches the tendo Achillis. The latter is usually ruptured in place of fracture of the calcaneum from muscular violence. The displacement of the fragment is sometimes slight, sometimes extreme, 11 cm. ($4\frac{1}{2}$ in.) (Constance). In fractures of the calcaneum from muscular action, and often in other fractures of this bone, dorsal flexion causes local pain by the traction of the taut tendo Achillis on the posterior fragment. *The astragalus* alone may be *fractured* by falls, but the lesion is often associated with fracture of the calcaneum, or at the ankle, etc. *Fracture of the other tarsal bones, the metatarsals, and the phalanges* is commonly due to direct violence. Such fractures are often compound, owing to the scanty covering of soft parts on the dorsum of the foot, which are usually contused or lacerated. I have observed one case in which fracture of the tubercle at the base of the fifth metatarsal bone occurred on both sides, at an interval of several months, by avulsion of the peroneus brevis tendon in a sudden inversion of the foot. The fracture was shown by the x-rays.

The Toes.—The toes very closely resemble the fingers, except in size, and are liable to similar lesions from injury, inflammation, etc., though not so frequently. **Dislocation** of the proximal phalanx of the great toe is similar to that of the like joint of the thumb in the character of the lesion, the difficulty of reduction, and the reasons for this difficulty. A peculiar affection of the toes known as "**hammer toe,**" in which the proximal phalanx is extended while the middle is strongly flexed, is most often found in the second toe, which is normally longer than the others. It is *due to* a contraction of the extensor tendon and of the glenoid and lateral ligaments of the first phalangeal joint.

The cutaneous nerve supply of the lower extremity is shown by Figs. 191 and 192.

Paralysis of the Lower Extremity.—Paralyses of the lower extremity are common and usually due to a lesion of the cord, hence they involve all or a considerable group of nerves. Occasionally a single nerve trunk is paralyzed by a cord lesion or a lesion of the nerve below its exit from the spinal canal. This involves a limited area of anesthesia or motor paralysis. An example of motor paralysis of a group or groups of muscles is seen not infrequently after infantile paralysis.

Paralysis of the anterior crural nerve may be *due to* fractures and tumors of the pelvis or spine, psoas abscess, dislocations of the hip, stab wounds in the groin, and perhaps a partial lesion of the cauda equina. If the entire nerve is paralyzed *the patient cannot* flex the hip, as in rising from the recumbent position (iliopsoas and pectineus), or extend the knee (quadriceps), and the knee jerk is lost. The sartorius is paralyzed, the pectineus partly so, being supplied in part by the obturator. In the parts supplied by the internal and middle cutaneous and the long saphenous nerves *anæsthesia* exists.

The obturator nerve *alone is seldom paralyzed*, but may be, occasionally, from the pressure of the fetal head or an obturator hernia or from lesions similar to those paralyzing the anterior crural. *The patient cannot* adduct the thighs or cross the legs (adductors), and outward rotation of the thigh is impaired (obturator externus and adductors). *Sensation* of the cutaneous area supplied (mesial aspect of thigh) is impaired.

Paralysis of the external popliteal alone is not uncommon, that of the **internal popliteal** is rare. It is usually due to infantile paralysis, to traumatism below the bifurcation of the great sciatic, and sometimes to pressure within the pelvis on the sacral plexus. In the latter case the external popliteal (peroneal) nerve is the one usually paralyzed, for its fibers arise mostly from the lumbosacral cord which is exposed to pressure where it crosses the pelvic brim. The anterior tibial branch or the entire peroneal nerve are the nerves that most often remain paretic after infantile paralysis. The peroneal nerve may also be injured in tenotomy of the biceps tendon, and still more often where it winds around the fibula, below its head, by pressure between the bone and the operating table, a splint, etc., by contusion at the same point, by fractures of the fibula or by a sudden strain. *In paralysis of the internal popliteal nerve the patient cannot* extend the ankle, flex or stand upon the toes (muscles of the back of the leg), or move the toes laterally (short muscles of the sole). Adduction and supination of the foot is impaired (tibialis posticus). The *sensation* in the skin of the sole, the plantar surface and ends of the toes, the outer border of the foot, and the back of the leg is impaired. *In paralysis of the external popliteal nerve the patient is unable to* flex the ankle, abduct or pronate the foot, or fully extend the toes (anterior leg muscles and peronei). Hence the toes drag in walking ("*drop foot*"), so that the knee must be unduly flexed to prevent it. Adduction and supination are impaired (tibialis anticus). Only the ends of the toes can be extended by the interossei. The arch of the foot may be somewhat flattened by the paralysis of the peroneus longus. In some cases the anterior tibial muscle escapes paralysis. The anterior tibial nerve has been injured in fractures of the tibia. *Sensation* over the outer side and the adjacent part of the front and back of the leg and the dorsum of the foot is impaired.

In paralysis of the great sciatic flexion of the knee is lost (hamstrings), and external rotation of the thigh is impaired (obturator internus and quadratus femoris) in addition to the results of paralysis of both the

internal and external popliteal nerves. Paralysis of the great sciatic *may be due* to pelvic tumors. These more commonly cause a *neuralgia* of the nerve. Paresis or neuralgia of the individual nerves of the lower extremity may be produced by similar causes. Hence it must be borne in mind that pain in any part of the lower extremity may be due to lesions at a distance, intraspinal, intra-abdominal, intrapelvic, etc.

In the diagnosis of the situation of lesions of the cord, due to disease or fracture, a knowledge of the skin areas and the muscles of the lower extremity supplied by the several segments of the cord is important. For this see the chapter on the Spine.

CHAPTER VII.

THE SPINE.

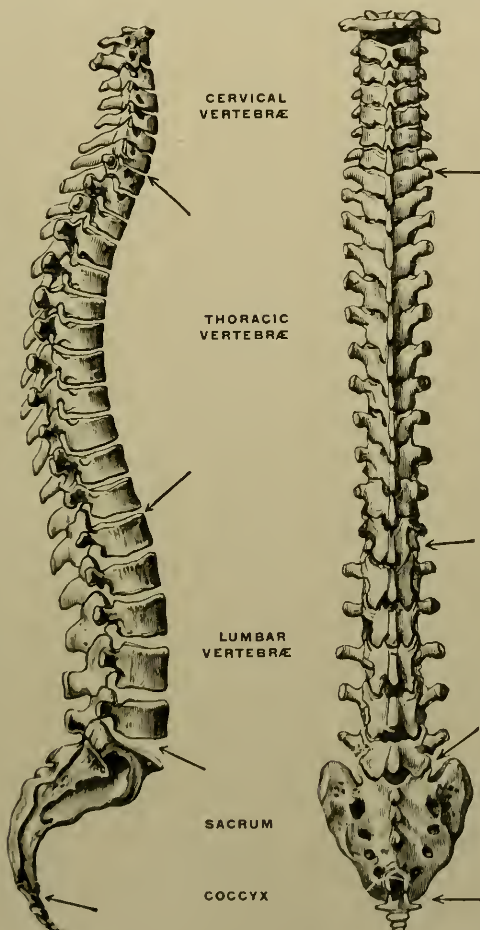
Landmarks and Topography.—By deep pressure a little below the occiput the spine of the axis may be felt. The spines of the next three vertebræ can only be felt with much d fficulty on account of their shortness, the presence of the ligamentum nuchæ, and the forward curve of the cervical vertebræ. That of the sixth cervical may be nearly as long as the seventh (Fig. 193) and is easily felt. When exposed by incision it may be distinguished by being the last bifid spine, as a rule. On account of the prominence of the spine of the seventh cervical the latter is called the *vertebra prominens,* but the spine of the first dorsal is the most prominent. However, we usually *begin to count the spines from the seventh cervical.* But unless all can be felt from the second down, it is safer to confirm the count by counting up from the fourth lumbar, unless the sixth cervical is to be exposed by incision. *The third thoracic spine* is on a level with the inner end of the spine of the scapula; *the seventh* with the lower end of the scapula; *the fourth lumbar spine* with the highest part of the iliac crest and the bifurcation of the abdominal aorta; *the second sacral spine* with the posterior superior iliac spine and the centre of the sacro-iliac joint; the third sacral spine with the upper border of the great sciatic notch; and the first piece of the coccyx with the spine of the ischium. The twelfth rib leads to the twelfth thoracic vertebra. The umbilicus is on a level with the interval between the third and fourth lumbar spines. The thoracic spines are oblique and overlap one another, in the middle of the series being opposite the disk below the next lower body. The broad lumbar spines are more horizontal and are opposite the disk (and the upper part of the body) below it. *The transverse process of the atlas* is palpable a little below and in front of the tip of the mastoid process, moving with the head in rotation. The anterior tubercle of the sixth cervical vertebra (carotid tubercle) is felt on a level with the cricoid cartilage. *The bodies of the upper three cervical vertebræ* only can be satisfactorily felt through the mouth at the back of the pharynx, the anterior arch of the atlas being on a level with the hard palate.

The spinal column is required to serve many different functions: (1) to bear the weight of the head and upper extremities; (2) to give attachment to the ribs; (3) to serve as the central axis of the body, to connect its upper and lower segments; (4) to diminish the effect of shocks and jars; (5) to allow of varied and extensive movements, and yet (6) to provide a solid canal which safely contains the spinal cord.

Corresponding to the increasing weight to be borne by the vertebral

bodies, as we pass from the upper end of the spine to the sacrum, we find that *their surface area gradually increases* from above downward. To allow the varied and extensive movements without injury to the delicate cord within, the spine is composed of a number of small articulated segments, the movement between any two of which is not great, while that of the spine as a whole is quite considerable. More free move-

Fig. 193



The spinal column, right lateral view and dorsal view. (Gerrish, after Testut.)

ment between a smaller number of segments would not only weaken the spine and make it more liable to injury, but also expose the cord to compression by being sharply bent, as it is in diastasis of the spine.

Of the **four anteroposterior curves** only two, *the thoracic and sacral, are present at birth.* These are *primary curves, due to* the shape of the bones, and are *convex backward* to give more room in the thoracic and

pelvic cavities, which they help to form. *The cervical and lumbar curves, convex forward,* are principally *due to* the shape of the intervertebral disks. They become developed from the weight of the body and the traction of the muscles when the erect position is assumed, and are more or less fixed about the sixth or seventh year. They are *compensatory curves* to allow the child to sit or stand erect. Otherwise the head would project forward and a marked dorsal convexity would exist in the thoracic region. This position is seen in the aged, in whom it largely depends upon the shrinkage of the disks, whereby the compensatory curves dependent upon them are flattened, and thus the primary permanent thoracic curve is exaggerated.

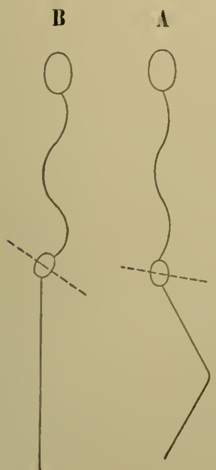
The *normal curves* of the spine *may be exaggerated* so as to constitute the several forms of **curvature of the spine.**

Increase of the posterior convexity in the thoracic region is known as **kyphosis.** This is almost always due to a tuberculous caries of the bodies of the thoracic vertebræ, and is known as "*Pott's disease of the spine.*" When the softened spongy tissue of the affected vertebral bodies yields to the pressure of the superincumbent weight the spine bends forward above the seat of the disease, thereby *throwing backward the spinous processes* opposite the diseased area. This gives rise to an *angular curvature or hump back,* which is accompanied by an increase of the cervical and lumbar compensatory curves. Hence to avoid deformity and allow healing in spinal caries, the superincumbent weight should be relieved by apparatus (plaster jacket) or posture. When the disease attacks the cervical or lumbar vertebræ there is no marked angular curvature, but the normal posterior concavity of these regions is flattened out and the affected part of the spine is rendered stiff. The neural arches and the circumference of the vertebral canal almost always escape the tuberculous process.

The spinal caries is often associated with abscess which tends to sink in the line of gravity along the spine. Spinal abscesses in the thoracic or lumbar region tend to enter the sheath of the psoas muscle, in the former region after passing beneath the internal arcuate ligament. They are *the common cause of psoas abscess.* If the curvature is extreme, or comes on rapidly, the front of the cord may be pressed upon by the projection at the back of the vertebral bodies and *motor paralysis results.* More often the cord symptoms are due to the pressure of inflammatory thickening, deposit or abscess within the canal, which also first press on the anterior or motor portion of the cord, for they are derived from the lesion in the bodies, anteriorly. They may subside from general treatment, but if degenerative changes in the cord appear the spinal canal should be opened to remove the cause of pressure. In recent years *angular curvatures* of the spine have been *successfully treated by forcible straightening.* This must create a gap anteriorly between the bodies equal to the amount of the loss or compression of the bone. It is not without risk. In severe cases the chest becomes much distorted and the lower ribs, resting on or below the iliac crests or sinking into the pelvis, obliterate the iliocostal space.

Lordosis is *an increase of the forward curve,* as in the lumbar and cervical regions. It is most marked and *most often observed in the lumbar region.* It is *almost invariably a compensatory curve* instinctively assumed to keep the centre of gravity from being advanced too far and to allow the patient to stand erect. Thus in obesity, pregnancy, angular curvature, congenital dislocation of the hips, and in *hip disease* with

Fig. 194



Diagrams to show lordosis as a compensating curve in hip disease: *A*, normal spinal curves. The hip is ankylosed in the flexed position; *B*, the ankylosed flexed hip is straightened by a tilting of the pelvis, indicated by the position of the dotted line and the presence of lordosis.

Fig. 195

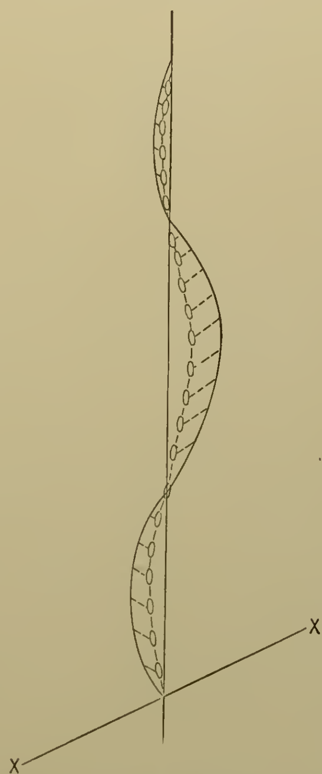


Diagram to show lateral curvature of the spine. The primary curve is to the right in the thoracic region, the compensatory curves in the opposite direction in the cervical and lumbar regions. The vertebral spines are shown rotated toward the convexity of the curve.

flexion of the femur, it is present as a compensatory curve. The latter condition is *its commonest cause.* The hip being held or ankylosed in a flexed position, the patient is only enabled to straighten it by a rotation of the entire pelvis, by which its upper end is moved forward, which increases the lumbar curve. This is seen in examining such a patient in the supine position. When the affected extremity is extended the lum-

bar spine is arched forward; when it is flexed to the angle in which it is ankylosed the lumbar curve is normal; and when it is further flexed the curve is straightened and the lumbar spines press the hand against the table.

Scoliosis or Lateral Curvature.—Scoliosis or lateral curvature may also be said to be *an exaggeration of a normal curve,* for very few are without a slight lateral spinal curve, usually to the right in right-handed persons. Scoliosis also *may be a compensatory curve,* compensating the lateral tilting of the pelvis which accompanies hip disease (p. 402) or an inequality of the length of the legs. It may be due to chronic empyema, or the extensive resection of several ribs to cure it. *More often it is an idiopathic condition* whose etiology we do not fully understand in many cases. It occurs in children, most often in girls, in whom the muscular development and general condition are below par. A faulty attitude in sitting at study or in standing is the most common cause. As *the principal curve,* in the upper thoracic region, is *usually convex to the right* in right-handed persons, unequal muscular action is thought to be a causative factor. There are, of course, compensatory curves in the opposite direction in the lumbar and often in the cervical regions to allow the erect attitude. In addition the vertebræ of the curved portion are rotated or twisted on a vertical axis, so that the bodies always turn to the convex side of the curve. These changes are due to the yielding of the bone to static causes and abnormally distributed pressure. They occur in the normal spine when it is bent laterally. When the faulty position is long maintained the vertebræ become wedge-shaped at the apex of the curve, lozenge-shaped above and below, and much distorted, as if the part behind the centrum were bent toward the concave side. This brings the spines nearer the median line, so as to diminish the appearance of the curve as indicated by them. It also *carries the ribs backward on the right* and forward on the left, so that the right chest is prominent posteriorly but flattened anteriorly, while the left chest is prominent in front but its ribs are more oblique and crowded together. The right lung is compressed and most of the work must be done by the other. Tuberculous affections of the apex of the lung are present in a large majority of such patients, usually on the side of the convexity of the curve. The scapula on the convex side is prominent posteriorly and elevated. The iliocostal space is diminished, but the ilium is more prominent on the concave side. In time the vertebræ, muscles, and ligaments become atrophied and contracted on the concave side, stretched on the convex side.

The **spinal canal is** *completed* posteriorly by the fusion of the laminæ, or neural arches, at the root of the spinous processes. Each half of the neural arch is formed from a separate ossific centre. Failure of this fusion causes a posterior median defect of the laminæ and spines which is seen in spina bifida. This is most common in the lumbosacral region, for here the neural arches are last ossified and fused together. Other imperfections of development are often associated with spina bifida.

Spina Bifida.—Spina bifida is a congenital defect of the vertebral canal through which some of its contents protrude, *i. e.*, (1) the meninges alone may protrude as a sac containing cerebrospinal fluid (*spinal meningocele*); (2) the sac may also contain a portion of the flattened cord or, generally, on account of its position the nerve trunks of the cauda equina, which usually adhere to the posterior wall of the sac (*meningomyelocele*); (3) the sac may consist of the dilated cord, enclosed by its membranes, containing a sac-like dilatation of its central canal (*syringomyelocele*). The second variety is the most common, the first, the next, and the third the rarest. In all forms *the sac is filled with* cerebrospinal fluid, in the first two forms from the subarachnoid space. Hence the sac, which forms a median dorsal tumor, is more tense in the upright position and on crying. Pressure may return some of the fluid and, by increasing the pressure within the spinal canal, may result in causing irregular muscular movements or even convulsions. Meningoceles give no symptoms but the presence of the tumor, as a rule. In the other two forms, however, paralysis of the rectum and the bladder with more or less paralysis and sensory disturbances are usually present. These involve the lower extremity owing to the common site of the defect in the lumbosacral region. These symptoms usually depend upon a defect of the cord or nerve roots, but they may be due in part to pressure. In *spina bifida occulta* there is a defect of the neural arch, but no hernia-like protrusion. There may be other tumors, such as lipomata, in, over, or beneath the bony cleft. The skin over the cleft presents a hairy patch. In *rachischisis* there is an entire absence of union of the walls of the medullary canal, including the bone and the cord, which forms the walls of the central canal.

The twenty-three **intervertebral disks** make up nearly one-fourth of the length of the spine, hence the height of the body is appreciably decreased from their compression on long standing or sitting, and in old age from the shrinkage of the disks. It is owing to the disks that the *movements of the spine* are permitted, and these movements are most free where the vertebræ are smallest or the intervening disks thickest, *i. e.*, in the cervical and lumbar regions respectively. Therefore movement is most free where the spinal canal and cord are the largest, where the curve is convex forward, and where there are no bony cavities containing viscera. Free movement in the thoracic region would be a distinct menace to the thoracic viscera. The degree of mobility depends upon the thickness of the disks, the size and shape of the bodies, and the direction of the articular and spinous processes. Movement is most free in the lumbar region, next in the cervical region where rotation and lateral motion are the freest, and least free in the thoracic region. The movements of the spine are less free than often supposed. Flexion is most free in the lumbar region, extension in the lumbar and last two thoracic vertebræ, which functionally are like the lumbar vertebræ. Lateral bending is always accompanied by a rotation of the bodies of the vertebræ to the convexity of the lateral curve in the thoracic region and to its concavity in the cervical and lumbar regions. This movement

is greatest in the cervical and upper thoracic regions in flexion of the spine, and at the dorsolumbar junction in extension of the spine (Lovett).

The vertebral bodies with the intervening pulpy portion of the disks really form ball-and-socket joints, but the *free movements* thereby allowed are *resisted by* the connecting ligaments and *restricted by* the articular processes and in parts by the other processes of the vertebræ. Owing to the more or less horizontal surfaces of the articular processes of the *cervical region,* movements in all directions are permitted there. Rotary movements are most free in the atlo-axoid joints, flexion and extension in the occipito-atloid joints. In the *thoracic region* extension is prevented by the overlapping spines and by the shape of the articular processes. The latter limit flexion also, whereas lateral movements, otherwise possible, are limited by contact between the ribs. In the *lumbar region* lateral movements are limited by the great transverse diameter of the bodies, rotation by the relation of the articular processes.

The *overlapping laminæ protect the cord* from injury in the thoracic region, where, owing to the curve, it lies nearer the surface and is most exposed. *Between the upper cervical vertebræ* the intervals between the narrow laminæ are widest, and here *the cord can be most easily reached and wounded* by a narrow instrument. Infanticide has been accomplished by pithing the upper cervical cord by a long narrow pin, thrust between the upper cervical vertebræ or between the atlas and the occiput. Again, *in the lumbar region it is possible to enter the spinal canal* by an instrument thrust obliquely upward and forward. This is taken advantage of **in lumbar puncture and spinal anesthesia.** *The puncture is made* between any two lumbar spines below the second lumbar vertebra (usually between the third and fourth), to avoid the cord which extends to the lower end of the first lumbar. To avoid the spines the puncture is made a little ($\frac{1}{2}$ to 1 cm.) to one side of the median line. In adults the puncture is made just outside of the upper margin of the spinous process below the interval, to give the needle the desired upward obliquity. *The needle is then thrust forward,* toward the middle line, *and in adults slightly upward, for* 2 *to* 7.5 *cm.,* until the escape of fluid (cerebrospinal) indicates that its point has entered the subarachnoid space. This occurs at a depth of 2 to 3 cm. ($\frac{4}{5}$ to $1\frac{1}{5}$ in.) in children and 4 to 7.5 cm. ($1\frac{3}{5}$ to 3 in.) in adults. The canal is entered through the ligamentum subflavum, which is felt to offer slight resistance to the passage of the point. The puncture of one of the nerves of the cauda equina may possibly occur and is shown by the twitching of some of the muscles of the lower extremity.

On account of the number of the joints and ligaments of the spine and the variety and extent of its movements it is readily understood why *the spine is liable to* **sprains.** That these sprains are not more common is due to the very number of the joints which tend to diffuse the force applied to the spine. These naturally *occur most often* where the movements are most free, *in the lumbar and cervical regions,* and where fixed and movable parts of the spine join one another, at the dorsolumbar and the cervico-occipital junctions. The nearness of the head

and the transmission of violence, received by it, to the spine may increase the tendency to sprains in the cervical region, especially where it joins the head. Considerable pain and stiffness often persist long after the injury, and these may depend upon a synovitis of one or more of the many vertebral joints. Ecchymosis rarely appears in these cases, for the spine is separated from the skin by many layers of muscles and fasciæ.

When the violence applied is more concentrated or more severe, **fractures or dislocations** of the spine are produced. *The liability* of the spine *to these accidents* is, to be sure, *diminished by* its elasticity, due to its curves, its disks, etc., and by the number of its segments. Some have even denied the possibility of dislocation of the spine without fracture, except perhaps in the cervical region, where the small size of the bodies and the less firm interlocking of the more horizontally directed articular processes do not offer so much resistance to the separation of the vertebræ. But in many cases the associated fracture is unessential to the production of the dislocation.

Dislocation.—Dislocation is *most common in the cervical region,* especially between the fifth and sixth vertebræ. Thoracic and lumbar dislocations are very rare, and mostly involve the twelfth thoracic vertebra. The dislocation is almost always of the upper vertebra forward, and may be complete or incomplete, bilateral (dislocation by flexion), or unilateral (dislocation by abduction and rotation). In the latter form the articular facet of one side is dislocated forward in front of the corresponding facet of the vertebra below, and the axis of its displacement passes through the articular facets of the other side. In this form there are no, or very slight, symptoms of injury of the cord, for the lumen of the canal is but little invaded. Bilateral dislocations are commonly due to overbending of the spine, especially hyperflexion.

Most dislocations of the spine are partly dislocation and partly fracture, and as it is usually impossible to distinguish between the two lesions, furthermore as the effects of the two are similar, it is best to consider them together. The term *fracture dislocation* is often applied to all such injuries of the spine. About 20 per cent. of spinal injuries are pure dislocations, 20 per cent. pure fractures, and the rest fracture dislocations.

Fracture of the Spine.—Fractures of the spine may be *due to indirect or direct violence.* Those due to the latter are rare and usually confined to the spines and laminæ in the thoracic or cervical region. The injury to the cord is less severe and less common, as a rule, in this class of cases, for much displacement is rare.

Fractures from Indirect Violence.—Fractures from indirect violence are *usually due to* a forcible bending of the spine in a fall or by the weight of a falling body. The breaking of the neck by diving in shallow water is an example. The *relative frequency* of the injury *in the lower cervical spine and at the thoracicolumbar junction* may be partly explained by the free mobility at these points, by the fact that at these points a flexible and a rigid portion of the spine meet, and, in the cervical region, by the small

size of the bodies. The eleventh and twelfth thoracic and the first lumbar vertebræ are fractured more often than any other three vertebræ and more than half the fractures of the spine occur below the tenth thoracic vertebra. Both regions where fractures are of common occurrence are far enough from the ends of the spine to be affected by powerful leverage from both sides. The sternum and ribs may act to some extent as a splint to protect the thoracic part of the spine. As most spinal fractures are due to forced flexion, the anterior portions of the bodies of one or more vertebræ are pressed together and more or less crushed and flattened, *compression fractures,* while the neural arches are pulled apart. It is noticeable that the large cancellous bodies are well adapted to resist compression, while the neural arches and their connecting ligaments are well suited to resist traction. These compression fractures occur most frequently at the dorsolumbar junction. If the violence continues, flexion of the spine may go on until the articular processes are so separated as to allow dislocation, and a fracture dislocation occurs. The kyphosis due to the isolated fracture is increased. In other cases with hyperflexion a *tearing fracture* occurs in an oblique direction from above and behind downward and forward, sometimes through two vertebræ. These fractures are usually fracture dislocations, though one or both of the articular processes may be fractured instead of dislocated. They present the greatest amount of displacement and occur most commonly at the cervicodorsal junction. In compression fractures and in all fracture dislocations there is more or less kyphosis opposite the site of fracture. Fractures or dislocations of the atlas and axis are particularly serious, owing to their relation to the medulla and their situation above the phrenic nerve roots. These injuries are immediately fatal if the cord is crushed. *The various processes may also be fractured* in a case of fracture dislocation. The following is the order of relative frequency for the various regions and processes: The spines in the thoracic, cervical, and lumbar regions; the transverse processes in the cervical, lumbar, and thoracic regions; the articular processes in the cervical, thoracic, and lumbar regions. Fracture of the articular processes increases the liability of displacement by removing one of the posterior processes which tend to lock the vertebrae together.

The displaced parts may often be *returned to the normal position,* particularly in the cervical and thoracic regions. This may occur *spontaneously,* so that on examination no irregularity of contour is discovered, or it may be done *by the surgeon.* The line of fracture is usually nearer the upper than the lower surface of the bodies, and there is more or less laceration of the contiguous disk in all cases, as well as of the ligaments connecting the spines, laminæ, and articular processes. The injury to the bones is the least important part of fracture dislocations of the spine; that of the contained cord is the most so. The latter from its size, which is smaller than that of the canal, and from its method of suspension in the vertebral canal (see p. 564), may escape injury, and is injured only when the lumen is considerably encroached upon by the displacement of the fragments. This displacement is almost always *of the upper frag-*

ment forward, or forward and downward, on the lower, and is most constant and most marked in fracture dislocations. The *cord is thus compressed against* the sharp posterior edge of the vertebral body below the line of fracture by the arch of the vertebra above. Thus *the anterior or motor portion of the cord suffers first and foremost,* and, if the crushing of the cord is not complete, sensation, which is partly conducted in the posterior part, may be retained in whole or in part. *The reflexes,* centring in the central gray matter, may also be preserved.

Symptoms.—The symptoms are largely *those of the injury to the cord.* In fractures in which there is or has been no displacement there may be almost no symptoms, except those of the fracture, resembling a severe sprain. *The external deformity shows* only a displacement of the vertebræ or a lesion of the laminæ and spinous processes. This external deformity *consists in* an anteroposterior or lateral deviation of the spines at the point of injury.

The spinal canal is opened by **laminectomy** in certain cases of fracture dislocation of the spine, especially when the symptoms do not indicate a complete crushing of the cord or when the lesion is below the level of the cord in the region of the cauda equina, as well as in some cases of pressure paralysis with beginning degeneration in Pott's disease, and in cases of tumors within the canal. *The cord* is then *relieved of pressure* by the removal of its cause. In this operation *the spines and laminæ are removed,* the latter as near as possible to the articular processes. The spines and laminæ are exposed by a *free median incision* and by the detachment and retraction to either side of the overlying muscles. Plexuses of veins on the outer and inner surfaces of the laminæ and along the spines may give rise to considerable *venous bleeding.* In some fractures or dislocations of the spine the displacement may be most readily and safely reduced by exposing the injured part, with or without removal of some of the processes or laminæ.

The Spinal Cord.

Topography.—The lower end of *the spinal cord,* corresponding to the tip of the conus medullaris, *extends* to the end of the spinal canal in early fetal life, to the third lumbar vertebra at birth, and to the disk below the first lumbar vertebra in the adult. It is raised 1 cm. when the body is bent forward and the arms are raised. **The spinal membranes,** containing cerebrospinal fluid, reach to the level of the second or third sacral vertebra, so that infected injuries here may produce spinal meningitis. The *cervical enlargement* is mainly opposite the fourth, fifth, sixth, and seventh cervical vertebræ, and measures 13 mm. transversely; the *lumbar enlargement* is largely opposite the eleventh and twelfth thoracic vertebræ, and measures 12 mm. transversely. In the thoracic region the cord *measures* 10 mm. transversely and 8 mm. anteroposteriorly. It averages 45 cm. ($1\frac{1}{2}$ ft.) *in length* and $1\frac{1}{2}$ ounces *in weight*

The manner in which the cord is suspended within the vertebral canal, which it does not nearly fill, accounts in part for its frequent escape

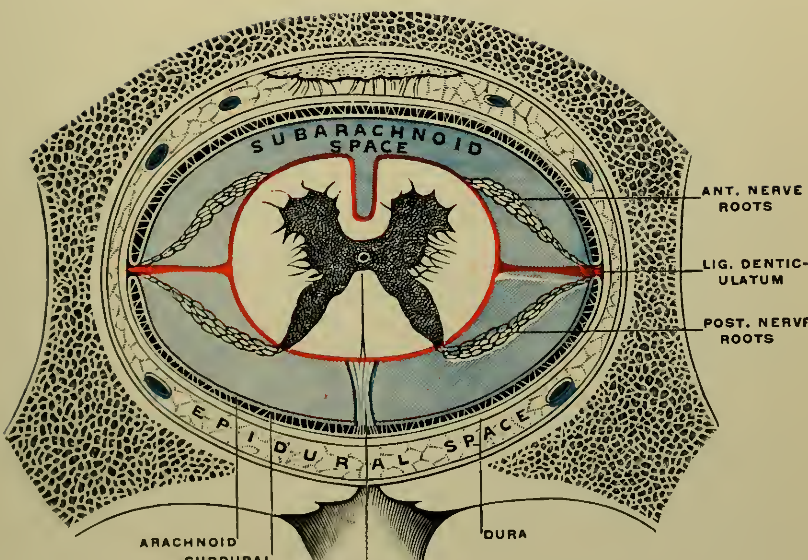
from injury. The strong **spinal dura** forms a tubular sheath (*theca*) for the cord and an investment for each nerve as it passes through it. It is *continuous with* the dura of the cranium, but, unlike it, *does not serve as the periosteum* of the bones bounding the canal, but is separated from them by a considerable interval containing loose areolar and fatty tissue and plexuses of veins. The latter may give rise to extensive *hemorrhage* in injuries to the spine, and the extravasated blood *tends to gravitate* toward the lower part of the canal, where sufficient quantity may collect *to cause pressure symptoms.* So *tough and loosely connected* with the bones is *the dura* that it is *usually untorn* by a fracture, even when the cord is completely crushed. In fact the contained cord is so delicate that it may be thoroughly disorganized without apparent alteration of its form. The strength and thickness of the dura is such as to offer considerable resistance to the invasion of disease from without, even to malignant tumors or tuberculosis. Inflammation of the dura, and also of the underlying meninges, after injuries of the spine, is much less frequent than similar complications after injuries of the skull. By the communication through the ligamenta subflava between the dorsal spinal veins, on the posterior aspect of the neural arches, and the venous plexuses within the canal, inflammation may travel from without to the spinal meninges. In this way spinal meningitis has followed carbuncle at the back of the neck or deep bed-sores over the sacrum.

The **subdural space**, or the space between the dura and arachnoid, in the spinal canal is merely a potential one, the two membranes being normally in contact, so that in dividing the dura we divide the outer layer of arachnoid and enter the **subarachnoid space**. The latter space *contains* a large amount of **cerebrospinal fluid** which surrounds the cord. The *cord is suspended in this fluid,* being connected with the layers of the meninges just mentioned only by the nerve roots and the ligamentum denticulatum on either side, and the delicate fibers of the arachnoid reaching from the dura to the pia, especially that dorsal median partition known as the septum posterius. These processes serve to steady the cord, surrounded by fluid, in its position within its theca. The cord is thus admirably protected from injury.

This fluid is continous with the subarachnoid fluid about the brain and, through the foramen of Magendie, with that within the cerebral ventricles. Thus in the case of a spina bifida, which contains this same fluid, fluctuation may sometimes be felt at the anterior fontanelle on compressing the tumor, and when the fluid is drained from a spina bifida so much may escape that the brain loses the support of its water-bed, and convulsions may occur from its irritation against the uneven base of the skull. Convulsions may also occur in lumbar puncture if the pressure is too much reduced. The *normal pressure of this fluid* in the recumbent position is said to support a column of water 5 cm. (2 in.) high, but in inflammation and some other diseased conditions it may reach a height many times greater. Normally *the fluid is absorbed* when its pressure is greater than that in the surrounding veins, and in diseased conditions the pressure may be relieved by lumbar puncture.

PLATE LIX

FIG. 196



Section of the Cord and its Membranes, to show the manner of suspension of the cord within the vertebral canal. Diagrammatic. (Testut.

In spinal anesthesia an amount of fluid is withdrawn equivalent to that of the solution to be introduced, so as not to alter the pressure. The *percentage of albumin in this fluid* is very low, 0.05 per cent., far below that of blood serum, but it is greatly increased in inflammation, and this increase is a diagnostic sign. **Lumbar puncture** is also *useful diagnostically* by allowing a bacteriological and microscopic examination of the fluid, and, as this fluid comes from about the brain as well as the cord, it is also useful in some cerebral conditions. Thus tubercle bacilli are often found in cases of tuberculous meningitis, and the diplococci of cerebrospinal meningitis in cases of the latter. The presence of numerous cells indicates inflammation and that of blood a pachymeningitis or an injury. *Therapeutically* it has proved of less value. It suggests itself in hydrocephalus, but is nothing more than palliative. In a few cases of spinal injury it appears to have been serviceable. By means of the free communication established by this fluid between the spinal and cranial cavities it affords a ready means of the spread of inflammation from one to the other. Blood extravasated into the subarachnoid space, in case of injury, may readily extend from end to end of the cord, and tends to gravitate toward its lower end, but extensive hemorrhage in this space is not common.

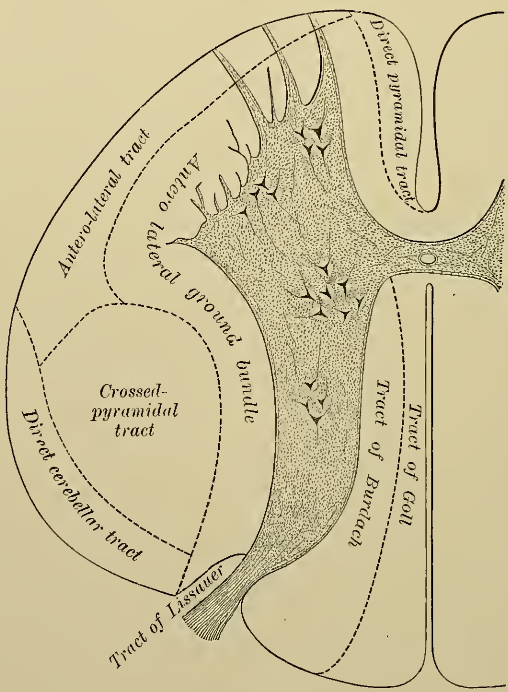
In spite of the marvellous provision for the protection of the cord, a train of severe and complicated symptoms sometimes follows certain injuries to the spine. These symptoms are attributed by some to **concussion of the cord,** comparable to concussion of the brain, but they are more complex than the symptoms of the latter. Concussion of the brain is of brief duration, but the long duration of the symptoms in question would indicate gross changes in structure, rather than the vague "molecular changes" often assumed as their cause, and the provisions for the protection of the cord would not admit of such a gross lesion from the injury received. If such symptoms *depend upon a distinct lesion* of the cord, it may very likely be a hemorrhage (*hematomyelia*), the diagnosis of which, says Thorburn, when the symptoms may be attributed to a single focus of injury, "should always be preferred to the vague and unsatisfactory designation 'concussion of the spinal cord.'" Many supposed cases of the latter will probably be eliminated by accurate study. Such a *lesion is probably due to* a partial dislocation with recoil, an acute bend, or a diastasis (separation) of the spine. The great majority, however, of these cases of supposed "concussion of the cord," known as "railway spine," because they so often occur in railway accidents, are examples of "traumatic neuroses.

Compression, Contusion, or Crushing of the Cord.—Compression, contusion, or crushing of the cord is what *constitutes the gravity of fracture dislocations* of the spine. Compression may also be due to tumors, inflammatory deposits, etc. As stated above, in fracture dislocations with displacement the cord is compressed or crushed by being pressed by the neural arch above the line of fracture against the sharp posterosuperior edge of the body below the fracture line. The anterior part of the cord is therefore first and, when the entire cord is not crushed,

most affected by the injury. It is important, therefore, both for diagnosis and prognosis, to know something of the **conduction paths of the cord** (Fig. 197).

Motor Tracts.—*The direct pyramidal tract,* or column of Türck, in the mesial part of the ventral column, conveys motor fibers from the cerebral cortex on the same side, which have not crossed in the pyramids. They eventually reach the opposite ventral horn by crossing through the anterior white commissure. They comprise about 15 per cent. of the pyramidal fibers, and extend to about the middle of the thoracic part of the cord. *The crossed pyramidal tracts* lie in the posteromesial part of

Fig. 197



Columns of the cord.

the lateral columns and convey motor fibers, which have crossed in the pyramid, from the opposite side of the cerebral cortex to the ventral horn of the same side. Lesions of these two columns cause a paralysis of the muscles below. The muscles are not atrophied unless the anterior cornu of gray matter is involved.

Sensory Tracts.—*The direct cerebellar tract* on the posterolateral aspect of the lateral column, separating the crossed pyramidal tract from the periphery, is an ascending or sensory tract of the second order, whose axones pass from the cells of Clarke's columns to the cerebellum. The *anterolateral or Gowers' tract* is another ascending sensory tract

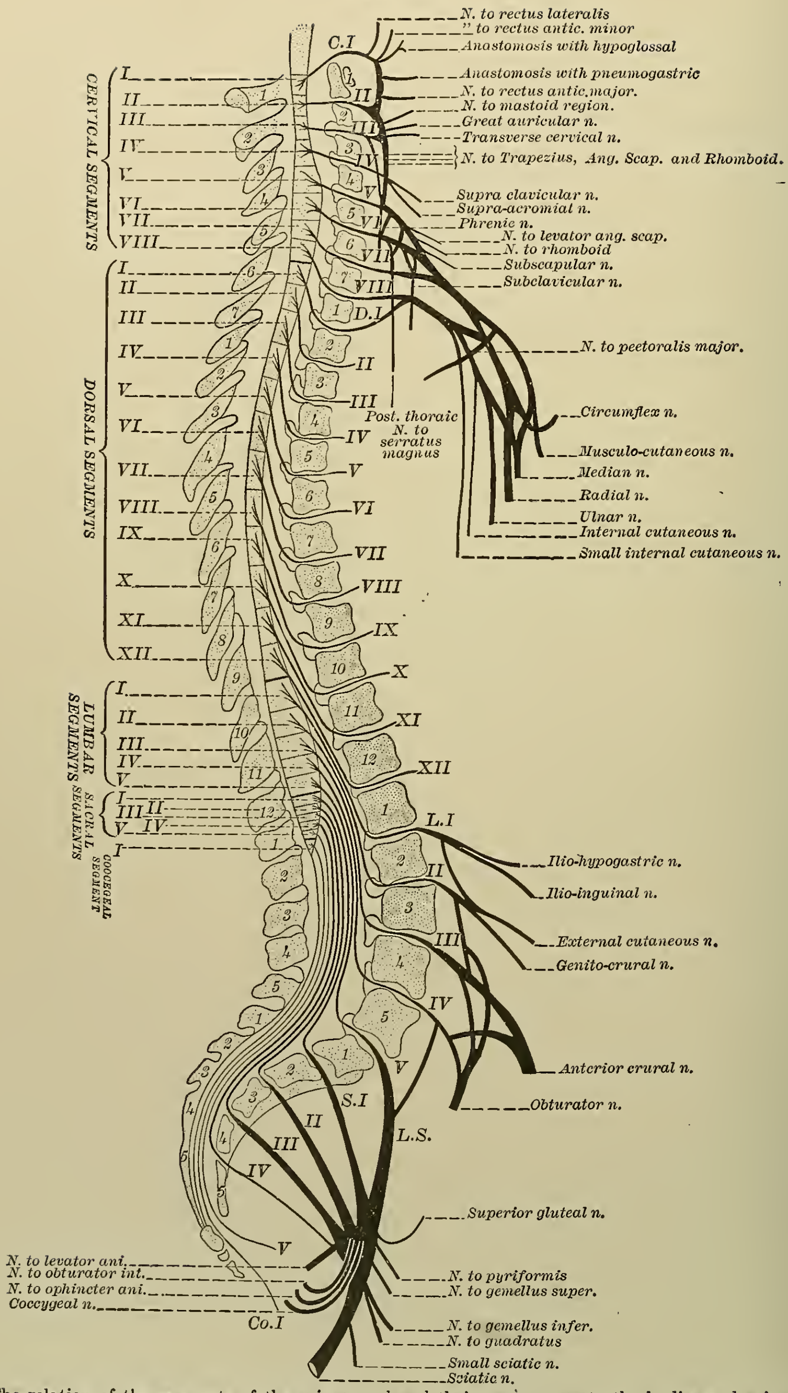
of the second order whose axones pass from the cells of the dorsal horn, partly from the same and partly from the opposite side, to the cerebellum and the lemniscus. *Goll's tract* (fasciculus gracilis) includes the dorsal or sensory root fibers that pass uninterruptedly in the posterior column to the nucleus gracilis of the medulla. These fibers first enter *Burdach's* tract and are gradually displaced medially into Goll's tract by the entry of new root fibers. Some of them pass up to the nucleus cuneatus of the medulla in the median part of Burdach's column. The lateral part of Burdach's tract receives most of the fibers entering by the dorsal root. These soon divide into ascending and descending limbs which give off collaterals, which, with the descending and some of the ascending stem fibers, pass into the gray matter to end about the cells of the dorsal horn and Clarke's columns. The rest of the ascending stem fibers pass up to the medulla in Goll's and Burdach's tracts.

Some (reflex) collaterals end in relation with the cells of the anterior horns, mostly of the same side. The latter complete the *reflex arcs* between the afferent sensory and the efferent motor fibers. Any loss of continuity in the arc causes the loss of the reflex. In the crossed pyramidal tracts are the *fibers which inhibit the reflexes* and thus keep them under control of the brain. When a lesion involves these fibers the inhibitory control of the brain is lost, the reflexes are exaggerated, and a spastic paralysis results. Subsequently the muscles become contractured.

The sensory tracts and centres of the cord are seen to be mostly behind, the motor in front. The posterior roots convey all forms of sensation, and all forms will be affected by a lesion in the lateral part (root zone) of Burdach's tract. After entering the cord the fibers conveying the several forms of sensation separate from one another and pursue different courses. Thus a lesion of the long sensory tract (Goll's tract) causes loss of muscle sense, or ataxia, with or without anesthesia. A lesion of the central gray matter causes analgesia and thermo-anesthesia, but no anesthesia.

The *trophic centres* of the motor roots and nerves are the nerve cells of the anterior horn. Destruction of these or division of the nerve roots, or their continuation in the motor nerves, causes degeneration, the reaction of degeneration, and finally the absence of all electrical reaction in the motor nerve fibers distal to the lesion which cuts them off from their trophic centres. The paralysis due to such lesions is flaccid and the reflexes are lost, for the reflex arc is broken. Rapid atrophy of the paralyzed muscles occurs. The *trophic centres* of the posterior or sensory roots are the cells of the ganglia of the roots. Section of the sensory fibers distal to the ganglia causes degeneration, etc., distal to the point of section, *i. e.*, in the fibers cut off from their trophic centres. After section of the posterior root between the cord and the ganglion degeneration occurs only centrally, from the point of section into the cord. Regeneration does not readily occur after such a lesion, as the degenerated fibers in the cord do not regenerate. All sensory functions of the root are lost, as it is cut off from the cord, but there is no degeneration distal to the lesion, as it is not cut off from its trophic centre.

Fig. 198



The relation of the segments of the spinal cord and their nerve roots to the bodies and spines of the vertebræ. (Déjèrine et Thomas, Mal. d. l. Moelle Épinière, Paris, 1902.)

The distinction between partial and total transverse lesions is important. In *partial transverse lesions* the level of the anesthesia may not correspond to that of the paralysis. The anesthesia may be incomplete or irregular in distribution. Paresthesia is often marked, and sharp root pains occur from pressure on the roots within the canal. The paralysis may be less rapid in onset, irregular in distribution, and variable in degree. The extensors often show more paralysis than the flexors. One side may be affected more than the other, and improvement may set in early. The deep reflexes are exaggerated or soon become so. The control of the bladder and rectum may not be lost, or, if lost at first, is early recovered from.

In *lesions of a part of the cord* only, as from compression of tumors, etc., the white tracts, being superficial, are first affected and lose their conductivity. The reflexes become exaggerated, for the reflex arc is intact and the cerebral inhibition is cut off (see above, p. 567). For the same reason the paralysis is spastic. In *unilateral lesions* the paralysis occurs on the same side as the lesion, but may be incomplete or early recovered from, owing partly to the incompleteness of the lesion on that side, partly to the fibers in the uninjured half of the cord, in the direct pyramidal tract, which cross below to the side of the lesion. This double innervation is limited, according to Wernicke and Mann, to the extensors of the thigh and knee, and the plantar flexors of the foot. In unilateral lesions the anesthesia occurs on the side opposite the lesion, except the muscle sense, which is on the same side. There is often hyperesthesia on the side of the lesion. From these clinical facts the conclusion is reached that sensory impulses pass across the cord and ascend in the columns of the opposite side.

In *complete transverse lesions* there is complete motor and sensory paralysis of all parts supplied by nerves arising below the level of the lesion. The paralysis is flaccid and the tendon reflexes are lost, though theoretically we would expect the reverse, for the reflex arc is intact. There is no trophic atrophy and no reaction of degeneration, for the trophic centres are intact. The vasomotor centres are paralyzed and, partly on this account, there is a tendency to decubitus and priapism. Control of the bladder and rectum is lost. There are, however, no symptoms which, except by their persistence, prove the presence of a complete transverse lesion.

In partial transverse lesions, when the paralysis and anesthesia do not correspond, and the deep reflexes are exaggerated or normal, or when the anesthesia is incomplete or irregular in distribution, *operation* (laminectomy) offers some hope and is justifiable. Many condemn operation *in complete transverse lesions* on the ground that the case is hopeless, but it is not invariably so, owing to the uncertainty of the diagnosis, and in many such cases great improvement or nearly complete cure has resulted. *The recuperative power of the cord* is considerable if its fibers are not severed, so that after severe crushing the function may be recovered to a greater or less extent. Recent experience in the surgery of the cord is, on the whole, encouraging, but

functional union of the divided cord has not been proved to occur, for regeneration does not occur in the fibers of the cord, a fact apparently associated with the absence of the neurilemma sheath. The *cauda equina* and the nerve roots are *practically peripheral nerves,* and hence resist trauma well, so that operation should be the rule in injuries of the cauda equina, especially if after six to ten weeks the bladder and rectum symptoms persist.

The determination of the level of the lesion is important not only in traumatic lesions, but even more so in those due to a tumor or an inflammatory deposit. For this purpose there are *three means at our disposal:* the extent (1) of the sensory paralysis and pain, and (2) of the motor paralysis, and (3) the condition of the reflexes. From these we can judge what nerve roots and therefore what spinal segments are involved. *The cord is divided into* as many **segments** as there are spinal nerves. *Each segment includes* the roots of a pair of spinal nerves, the dividing line between two adjoining segments passing transversely between the superficial origins of the pairs of nerve roots. It is to be noted that the distribution of the segments or nerve roots does not correspond to that of the peripheral nerves, but to parts of several. Thus, in the trunk the sensory areas are almost horizontal. The cutaneous sensory areas are shown in Fig. 199 and in column E, the motor distribution in column D, Fig. 200. Remember that the cervical nerves appear above their respective vertebræ, the thoracic and lumbar nerves below. The level of the anesthesia (and of the pain) is the most reliable indication for the niveau-diagnosis. The symptoms due to a lesion of a segment or of its nerve roots, at a lower level, are the same. The fact that formerly tumors, etc., localized by the level of the anesthesia were often found at a higher level is explained by the investigations of Sherrington, who showed that a single segment or root does not wholly supply a given area of skin (or a single muscle), but at least three (and Bruns says five) adjoining segments participate. Hence the cutaneous area of each spinal segment so overlaps those of the neighboring segments and the posterior primary divisions of the spinal nerves anastomose so freely with each other that a lesion of a single segment or posterior root does not cause anesthesia, for the area supplied by it is also supplied by the neighboring segments. It requires the division of three adjoining posterior roots to produce complete anesthesia. There may be hypesthesia or diminished or uncertain sensation in the area supplied. Hence the upper border of anesthesia, due to the pressure of a tumor, etc., points to a lesion of the next higher, or perhaps the second higher, segment than that represented by the level of the anesthesia, for the area principally supplied by the upper one of the affected segments is also supplied by the segment, or, perhaps, two segments above it. It has been shown that the upper end of a compressing tumor is in the segment corresponding to the highest zone of disturbed sensation, or the zone where diminished passes into normal sensation. Horsley says it is necessary to very accurately determine the upper border of the hyperesthetic and paresthetic zones, above the anesthetic zone, and the cord

should be explored to the highest level suggested by any definite symptoms, including even slight paresthesia. To allow for the possibility of slight individual variation and for any slight inaccuracy in the localization, as well as to afford room for the operative technique, at least three laminæ are exposed and removed.

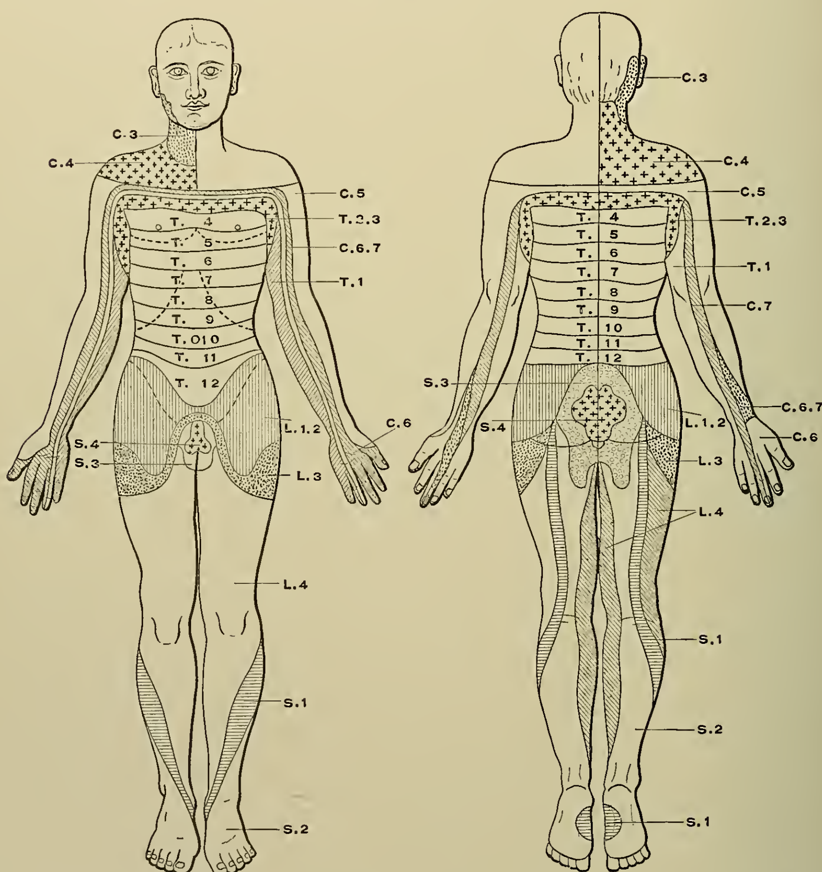
The distance, if any, that the afferent (and perhaps the efferent) tracts run in the cord before they reach their real centres is not definitely known. On account of this and of the downward course of the nerve roots from their spinal origin to their exit from the canal, and of the downward passage of the posterior primary divisions of the nerves to reach their areas of distribution, the spinal segments, and any lesion compressing them, are at a higher level than the corresponding segment zones on the skin of the back. In the dorsal region the cord segment is 10 cm. (4 in.) higher than the zone of anesthesia (Starr). The relations of the cord segments to the vertebral spinous processes (Fig. 199) has been reduced by Chipault to the following fairly accurate rule: To give the segment opposite a given spine, add one to the number of the vertebræ in the cervical region, two in the upper dorsal region, and three from the sixth to the eleventh dorsal. The lower part of the eleventh dorsal spine and the space below it are opposite the lower three lumbar segments. The twelfth dorsal spine and the space below are opposite the sacral segments. In operations for lesions of the cord the knowledge of the relations of the segments to the spines and bodies of the vertebræ is absolutely essential in order to know exactly where to operate, for the localization of the lesion is made with reference to the segments, and the spines are our only landmarks. These relations are shown in Figs. 198 and 200.

It is most important to remember that, as stated above, *the level of the segment*, or the superficial origin of the nerve from the cord, is *higher than the exit of the nerve* through an intervertebral foramen. In other words, the nerve roots run within the spinal canal and alongside of the cord for a distance which varies with different nerves and increases as we pass from the higher to the lower segments. These *nerve roots resist injury* far better than the soft cord, so that, as a rule, the nerve roots which, given off above, pass the site of the cord lesion are seriously involved only in the most severe injuries. It follows that, the site of the fracture being known, when the level of the anesthesia extends higher than would be expected from the level of the lesion, the lesion is so severe as to crush the nerve roots, and hence to completely sever the cord, and the prognosis is correspondingly bad. The nerves whose roots pass a spinal lesion may perhaps show some paresthesia, hyperesthesia, or pain, if they are merely contused or compressed, but the pain, like the anesthesia, is almost always referred to a lower level than the lesion, on account of the intraspinal course of the nerve roots, etc. (see above). They usually give rise to the first symptoms (nerve-root symptoms) in intraspinal tumors.

On inspection of the cutaneous *areas of anesthesia* corresponding to the several segments of the cord (Fig. 199), it will be seen that only

when the first lumbar segment is involved does the anesthesia extend up to the abdominal wall. By the area of anesthesia alone it is impossible to definitely distinguish severe lesions of the cauda equina from those of the segments from which they are derived, for the distribution of the anesthesia is practically identical. But most lesions of the cauda may be differentiated from those of the lower segments (p. 573). In all cases

Fig. 199



Cutaneous sensory distribution of the spinal segments on the anterior and posterior surfaces, from the third cervical to the fourth sacral, inclusive. (After Kocher.)

the localization of the injury of the cord must be made from the symptoms observed shortly after the injury, for within a few days myelitis is apt to occur and cause an upward extension of the area of anesthesia and paralysis.

For the interpretation of the muscular paralysis three methods of determining the segments which correspond to the nerve supply of the muscles *have been employed:* (1) the experimental, on monkeys; (2) the

clinical, from an accurate observation of cases; and (3) the anatomical, from minute dissections. Although perhaps less accurate than the others, *the clinical method* is still *of the most practical service,* and hence column D, Fig. 200, gives the results obtained by Thorburn from an analysis of careful clinical observations.

According to Thorburn no motor supply comes from the first and second lumbar segments, but many derive a part or the whole of the nerve to the cremaster from them. The paralysis which serves in the localization of an injury is that of the muscles whose nuclei are in the uppermost segment involved by the lesion, hence it is a flaccid paralysis with rapid atrophy, as its trophic centres (nuclei) are involved. It will be seen that *motor paralysis is slight in the lower cord lesions,* only the perineal muscles, bladder, and rectum being involved in lesions just below the second sacral segment, and, with the possible exception of the glutei, only the leg and foot muscles are affected in addition, if the lesion involves all the sacral segments.

In pressure lesions of the cauda equina, on the other hand, the pressure may be sufficient to cause widespread paralysis when sensation is but slightly affected. Hence in a lesion of the cauda equina the distribution of the paralysis may be much more extensive than would be expected from the distribution of the anesthesia, while in lesions of the cord the distribution of the two usually correspond. In *cauda equina lesions* the symptoms are less likely to be symmetrical in distribution than in lesions of the conus terminalis, and severe pain is more common than in lesions of the cord. Muscular atrophy accompanies the paralysis, for the muscles are cut off from their trophic centres in the anterior horn. As the pressure increases the reflex arc is broken and the reflexes are lost. Also in pressure lesions of the cauda equina the nerves which pass out lower down are first and most seriously involved, though they are situated nearer the centre and would appear to be less exposed to pressure, a fact that is not explained. *The cauda equina,* formed by the nerve roots of the lumbar and sacral segments, covers and conceals the lower end of the cord, so that no injury of the lumbosacral region of the latter can occur without an injury of the cauda, which may also be injured below the level of the cord. The sacral roots of the cauda have an intraspinal course of 12.5 to 15 cm. (5 to 6 in.). The dura, which encloses the cauda like a muff, is pierced by the roots opposite the foramina by which they emerge.

According to Starr *the control of the bladder and rectum* is always *lost together.* It is lost if the fourth and fifth sacral segments are involved, in which are the centres controlling these organs. *In a lesion involving these reflex centres* the reflex arc is broken and absolute passive incontinence follows temporary retention; the bladder first distends and then dribbles from overdistention. The rectum shows no tendency to empty itself. *In a lesion above these centres* the cerebral inhibitory control is cut off so that, after a temporary retention due to shock, the bladder and rectum are emptied at frequent intervals unconsciously and involuntarily. The reflex mechanism being intact works like a clock without a pendu-

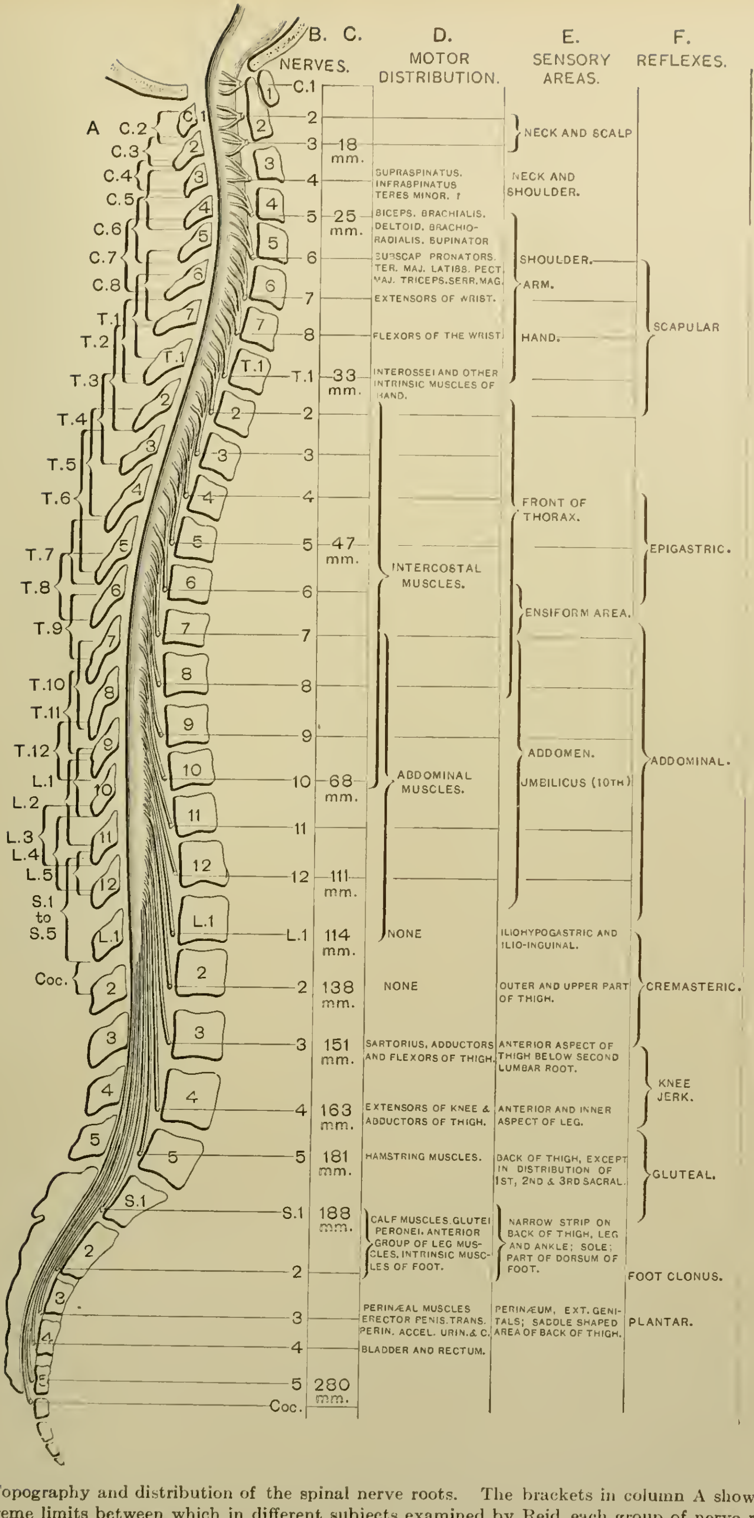
lum. This is known as active incontinence. Similarly in lesions above the *reflex centre of erection of the penis,* which is in the first three sacral segments the inhibitory fibers are cut off and a chronic erection (*priapism*) usually occurs.

Thorburn has called attention to *the pathognomonic posture* assumed *in lesions just below the fifth cervical segment* and the explanation of it. The arms are abducted by the deltoid, and rotated out by the supra- and infraspinati, the elbows are flexed by the brachialis, brachioradialis, and biceps, and the hand is supinated by the latter, all the other muscles of the arm being paralyzed. Such a position is assumed because the muscles controlled by the nerve cells just above the lesion, which causes the paralysis, are actively contracted by the condition of irritation into which these nerve cells are thrown. As *the phrenic nerve* is derived principally from the fourth cervical segment, receiving contributions from the third and fifth segments, lesions at or above this level are rapidly fatal from failure of respiration. In lesions between this and the upper thoracic segments the respiration is entirely diaphragmatic. Thus the higher the lesion in the cord the more serious is the prognosis. As the ciliospinal centre, whose stimulation causes the pupil to contract, extends from the sixth cervical to the third thoracic segment, and its fibers leave the cord to join the sympathetic with the eighth cervical and first thoracic roots, an irritative lesion of or above the first thoracic segment causes a narrowing of the pupil on the same side and perhaps profuse sweating of that side of the face and neck.

The integrity of the spinal reflexes depends upon that of the afferent sensory nerve, the efferent motor nerve, their connection in the gray matter of the cord, and the inhibitory fibers, descending in the crossed pyramidal tracts, by which the brain regulates the reflexes. If the latter fibers are destroyed by a lesion, all reflexes below this point are exaggerated from the loss of cerebral control. If the afferent or efferent nerves or their association in the gray matter is destroyed, the reflex arc is broken and the reflexes are lost. *The reflexes,* with the segments to which they correspond clinically, are given in column F, Fig. 200.

Hemorrhage may occur within the cord (*hematomyelia*) or within the membrane (*hematorrhachis*). The latter may extend the length of the cord or gravitate largely to the lower end, and produces no very localized symptoms. It almost never exists as an independent lesion. According to Thorburn, **hematomyelia** is not at all uncommon, and *occurs principally* between the fourth cervical and the first thoracic segments (inclusive), corresponding to the cervical vertebræ from the fourth to the seventh inclusive. This is the summit of the cervical curve, where an acute bend of the neck would make itself mainly felt. In fact, the cord has been crushed by such a bend without fracture, and with only temporary diastasis. The hemorrhage is generally due to an overstretching of the cord, in which the central gray matter is the chief seat of the lesion, for it is softer and more easily injured, though better protected, than the white columns. *The symptoms produced by such a hemorrhage depend upon* (1) a compressing and (2) a destroying lesion;

FIG. 200



Topography and distribution of the spinal nerve roots. The brackets in column A show the extreme limits between which in different subjects examined by Reid each group of nerve roots was found to arise. Column B shows each nerve cut off at the level of its intervertebral foramen, thus showing the obliquity of its course in the neural canal. Column C gives the vertical distance in millimeters which in Testut's case, of a subject eighteen years of age, separated the superficial origin of each of the nerves marked from its intervertebral foramen.

the former temporary and causing paralysis, disassociated anesthesia (thermo-anesthesia and analgesia without tactile anesthesia), loss of control of the reflexes of the bladder, rectum, penis, etc.; the latter permanent and causing atrophic paralysis, and perhaps anesthesia, of the parts supplied by some of the roots of the brachial plexus. *These hemorrhages* are usually confined to and *most severe in the centre of the cord,* so that the more peripheral fibers, which emerge near the lesion, may not be affected by the eccentric pressure, while the more central fibers, which emerge lower down, are more and more affected; hence the area of anesthesia is ill defined and may be far below the seat of the lesion. Some doubt is thrown on the correctness of this explanation by the fact, stated by Horsley, that the same tendency to involve the lowest sensory fibers first is found in the case of tumors, whose pressure is concentric. **In tumors** *the invasion of paralysis* is from above downward, or the reverse of that of anesthesia. The *favorite situation for tumors* is below the middle of the cervical region and at the upper and lower ends of the thoracic region.

Operations upon the cord, in addition to those for fracture dislocations, are not infrequently done for tumors, or inflammatory deposits, the operator being guided by the above and other minor points of localization. The cord is first exposed by a laminectomy. Such operations have been very successful when the tumor has been removed and the operation was not too long deferred.

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